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BATTERY CHARGER PP-4126 ()/U

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BOSE Corporation
Framingham, MA 01701

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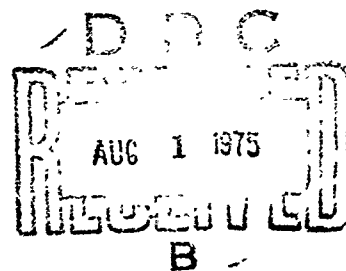
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The performance data and design configuration of the PP-4126()/U Battery Charger developed for ECOM in accordance with Development Description ED-CD2062-0001A dated May 16, 1969, are delineated in this final report. Performance of the unit is summarized. Terminal performance and selected aspects of internal performance are considered. The internal system configuration of the battery charger is presented in block form. Functions of internal system blocks are discussed to define their design and behavior. (cont on reverse side)		

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BLOCK 20- Continued

Circuit components used to implement the systems blocks are identified.

The PP-4126()/U Battery Charger is designed to charge 6, 12, and 24 Vdc batteries at selectable charging rates from 0.1 Adc to 12 Adc. The battery charger operates from MIL-STD-704 dc power sources in the range 22 Vdc to 40 Vdc. The battery charger structure is a finned housing with a removable cover. The cover contains the input power cable. The battery charger may be operated in any position.

Features of the battery charger are:

1. Power efficiency - greater than 80% at full 360 watt power level (28 Vdc source).
2. Three automatic modes of operation: Vented nickel cadmium, silver zinc, and sealed nickel cadmium.
3. Output current regulation/limiting-- $\pm 5\%$ (line and load).
4. Stability of transition voltage level-- $+0, -2\%$ (line load).
5. Precise resolution of volts, amperes, and hours control settings through the use of three and four place digital type controls.
6. Operation with ambient temperatures in the range -50°F to $+145^{\circ}\text{F}$.
7. Output short circuit and overload protection.
8. Output reverse polarity protection.
9. Output over-voltage protection.
10. Input reverse polarity protection.
11. Input over-voltage protection.
12. Compliance with the requirements of MIL-STD-1281 (EL), "Internal Transient Control for Solid State Power Supplies."

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1. INTRODUCTION, DESCRIPTION AND PROGRAM

1.1 Introduction

The PP-4126 (/)U Battery Charger is intended to charge 6, 12, and 24 Vdc (nominal) batteries at adjustable charging rates from 0.1 Adc to 12 Adc. The battery charger provides three switch selectable charge sequences to satisfy the requirements of sealed nickel-cadmium, silver-zinc, and vented nickel-cadmium batteries. All modes of operation are completely automatic, requiring only initial setup.

Front panel indication of the operational condition of the battery charger is provided through the use of a power indicator lamp and a relay tripped circuit breaker. Circuit breaker/power switch protection is provided for power input and power output connections to the battery charger.

The battery charger operates from 28 Vdc (nominal) power sources having the characteristics of MIL-STD-704A; 22 Vdc - 40 Vdc continuous, 0 Vdc - 80 Vdc transient (50 ms). The battery charger is shown in Figures 1 and 2.

The front panel controls, indicators, and connectors are listed in Table 1. A brief description of the functions of these panel elements is included. The locations of the front panel elements can be observed in the picture of Figure 2. When reference is made to a word appearing on the front panel, the word appears entirely in capital letters: VOLTS, AMPERES, SENSING, etc.

1.2 Modes of Operation

The mode of operation is determined by the mode selector switch which is located at the center of the front panel as shown in Figure 2. When the mode selector switch is in any of the battery charging positions, that is, SEALED NICKEL CADMIUM, SILVER ZINC, or VENTED NICKEL CADMIUM, constant output currents are provided when the battery charger is in active operation. The output current level is determined by the setting of the AMPERES control located at the top center of the front panel.

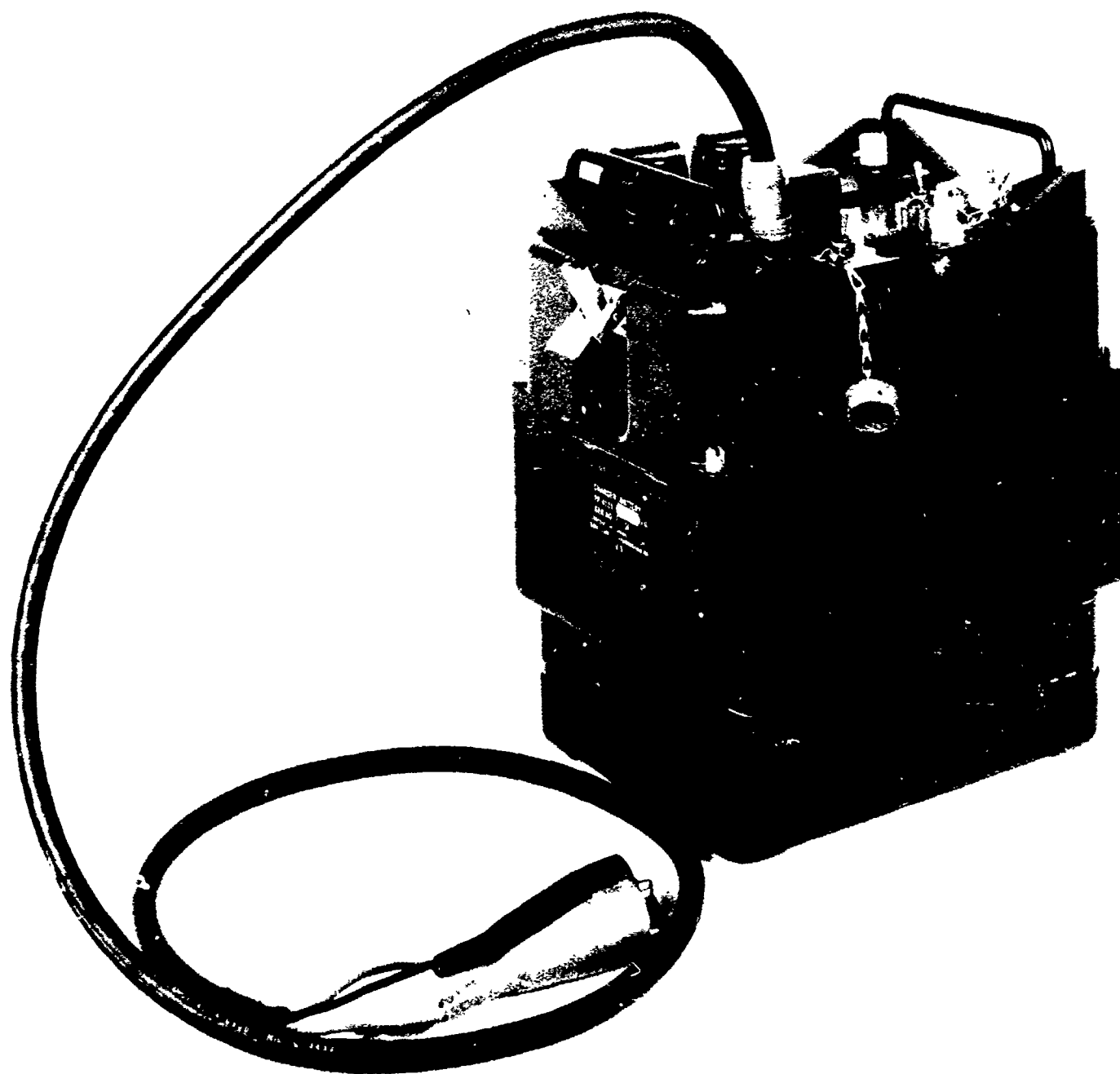


Figure 1. Battery Charger, PP-4125 ()/U
with Cover Removed and Cable Connected

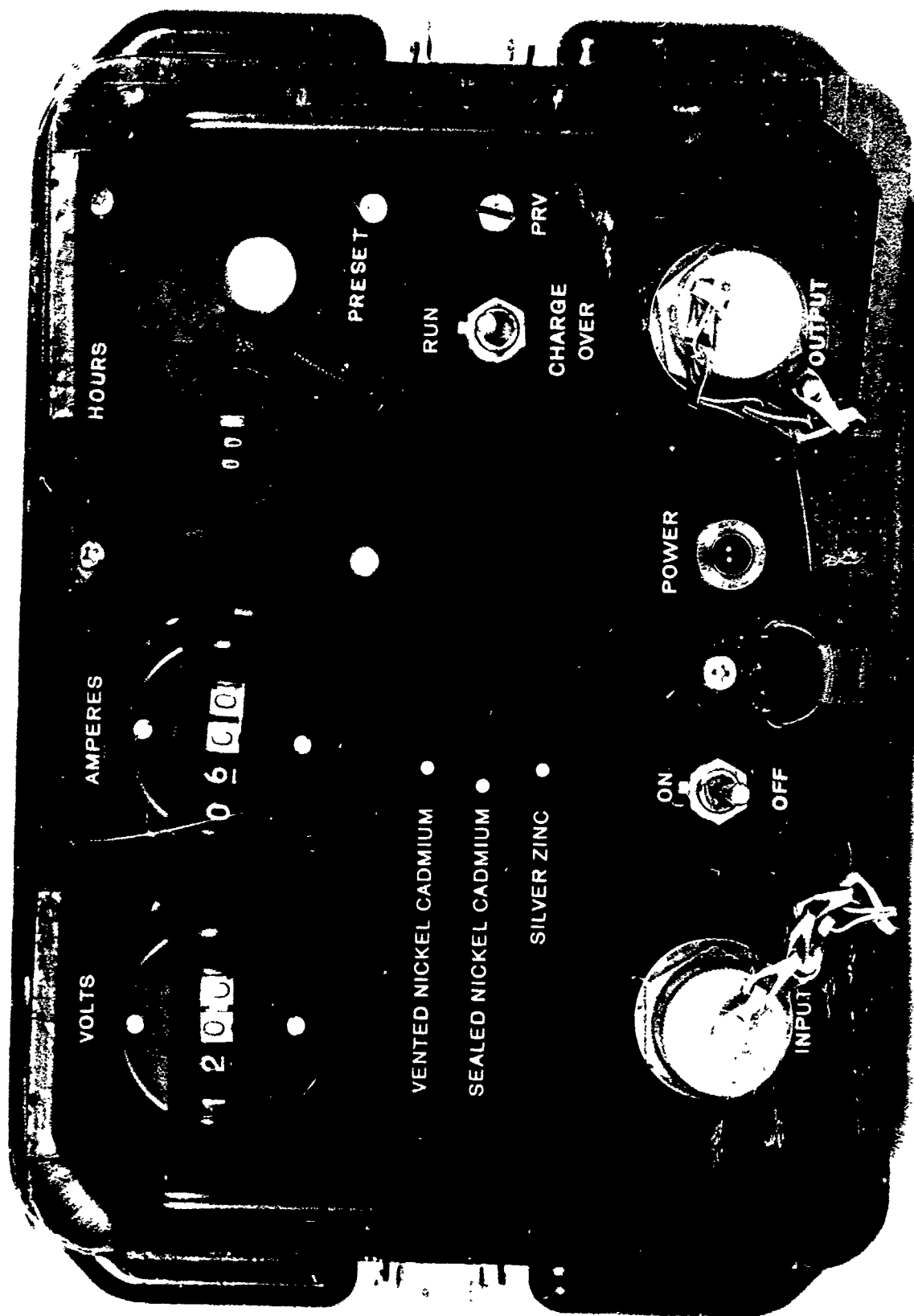


Figure 2. Battery Charger, PP-4126(U)/U
Front Panel

TABLE 1.
SUMMARY OF PANEL CONTROLS, INDICATORS,
AND CONNECTORS

CONTROLS	Position/Range	Function
Mode Selector	VENTED NICKEL CADMIUM	Selects appropriate battery charging cycle.
	SILVER ZINC	Selects appropriate battery charging cycle.
	SEALED NICKEL CADMIUM	Selects appropriate battery charging cycle.
VOLTS	00.00 - 45.00	Selects transition or cutoff voltage level in battery charging modes.
AMPERES	00.00 - 12.00	Determines output current in battery charging mode.
HOURS	00.0 - 15.9	Determines duration of timed battery charging sequences.
Power Circuit Breaker	ON/OFF	Protects input and output of battery charger.
Relay Trip Circuit Breaker	RUN	Initiates active operation of battery charger.
	CHARGE OVER	Initiates stand-by condition of battery charger.
Pressure Relief Valve (PRV)		When opened, equalizes pressure inside case with outside atmospheric pressure.
<u>INDICATOR</u>		
POWER Lamp		Indicates the presence of dc power in the battery charger.
<u>CONNECTORS</u>		
OUTPUT		Output connection from battery charger.
INPUT		Input connection to battery charger.

Battery charging cycles are terminated automatically when the battery voltage reaches a predetermined cutoff level or when a preset charging time has elapsed. The specific manner in which battery charging cycles are terminated is determined by the setting of the mode switch.

When the battery charger is in active operation, the relay tripped circuit breaker is in the RUN position. Following the completion of a battery charging cycle, the relay tripped circuit breaker automatically shifts to the CHARGE OVER position. The charge-over condition is a stand by condition indicating that the battery charger is not providing output power.

Sealed Nickel Cadmium

A timed battery charging mode of operation is provided for a specified time period. The duration of the charge period is controlled by the HOURS control located in the upper right-hand corner of the front panel as shown in Figure 1. At the end of the charge period, the battery charger electrically disconnects the battery.

Vented Nickel Cadmium

An automatic two-stage charge sequence is provided for Vented Nickel Cadmium batteries. During the first stage of the charge sequence, a programmed current is supplied to the battery. This continues until the battery voltage reaches a preset transition voltage selected by setting the VOLTS control. A second stage of charging is automatically initiated when the battery voltage reaches the set transition voltage level: A regulated topping current, 40% of the programmed current, flows to the battery. The topping current is supplied for a specific time which is determined by the HOURS control. At the end of the second charging stage, the battery is electrically disconnected from the battery charger.

Silver Zinc

In order to charge Silver Zinc batteries, a programmed current is supplied to the battery until the battery voltage reaches a preset cutoff voltage selected on the VOLTS control. After a delay of approximately 5 seconds, the charge cycle is terminated.

1.3 Controls

Rotary controls having digital indication of setting are utilized. These controls offer numerous advantages:

- 1) Settings can be made quickly by personnel not familiar with electronic equipment.

- 2) Clear, numerical indication of the setting insures proper control adjustment.
- 3) Settings can be made to 0.1% resolution.
- 4) Controls can be operated with gloved hands.
- 5) Settings can be locked with a simple locking mechanism.

Volts Control

The setting of the VOLTS control (c.f. Figure 1) determines the transition voltage. The function of the transition voltage setting is clear from the discussions of the battery charging cycles above.

Amperes Control

When the battery charger operates in one of the three battery charging modes, the setting of the digital AMPERES control determines the output current level. The AMPERES control is capable of selecting any current from 00.00 Adc to 12.00 Adc.

Hours Control

The HOURS control (c.f. Figure 2) programs charging time durations for Sealed Nickel Cadmium batteries or topping time periods for Vented Nickel Cadmium batteries. Time periods are preset by the operator by depressing and turning the adjustment knob. Time durations are carried in hours in decimal form; i.e., xx.x hours. When the HOURS control operates, it counts down from the preset number of hours toward zero (00.0); the front panel HOURS indication always shows the remaining charging time.

When the HOURS control indicates zero, battery charging is terminated. In either the SEALED NICKEL CADMIUM mode or the VENTED NICKEL CADMIUM mode, it is not possible to start the battery charger if the HOURS control reads zero. This requires the operator to preset a charging time duration before he can start the battery charger.

Run/Charge Over Circuit Breaker

A toggle action relay tripping circuit breaker is used to initiate and to terminate battery charging cycles. Indexing the circuit breaker to the RUN position causes the battery charger to commence operation. The position of the toggle handle serves as a simple and economical indication of the operating condition of the battery charger. When the battery charging cycle is completed, the circuit breaker automatically trips the CHARGE OVER position. This electronically disconnects the battery charger from the battery at the output.

1.4 Indicator Lamp

Power Lamp

A green POWER lamp indicates that input power is present and that the power circuit breaker is on.

Dimmer

The intensity of the POWER lamp may be dimmed by turning the lens.

1.5 Program

In July 1971 Contract DAAB07-71-C-0355 was awarded to BOSE Corporation for the design and fabrication of Six Engineering Test/Service Test PP-4126()/U Battery Chargers in accordance with Electronic Command Development Description EL-CD-2062-0001A, dated 16 May 1969 and Amendment No. 1 thereof, dated 4 September 1974. In addition to the units, the following testing and data items were required:

Test Plans

Qualification Test Plan consisting of all the electrical and environmental tests necessary to demonstrate compliance of the PP-4126()/U with the Development Description.

EMI Test Plan consisting of those tests necessary to demonstrate compliance with the required EMI specifications.

Test Reports

Equipment Compliance Report consisting of a report on the results of electrical and environmental tests of the unit.

EMI Test Report consisting of results of the EMI testing.

Final Technical Report--A final report summarizing the design and aspects of development was written.

All of the above items have been submitted and approved by the Electronics Command and the program was completed in July of 1974 with submission of this final report.

2. PERFORMANCE DATA

2.1 General

The performance of the PP-4126()/U Battery Charger is summarized in Table 2. Additional information regarding battery charger performance is available in the discussions below.

2.2 Input Voltages

The battery charger provides full output power, 360 watts, from dc power sources in the range 22 Vdc to 40 Vdc. Input voltages below this range result in a reduction of output voltage and current capability. Input voltages significantly below the nominal level cause the battery charger to stop active operation. However, when nominal input voltage levels are returned, the battery charger resumes operation. Input voltages exceeding the nominal ranges listed above cause an input over-voltage circuit within the battery charger to trigger, inhibiting battery charger operation until the input voltage returns to the nominal range. Transient voltages up to 80 volts may be applied to the battery charger without causing damage.

When an appropriate input voltage is supplied to the battery charger module, the green POWER lamp is illuminated.

2.3 Output Current

Output currents in the range 00.10 Adc - 12 Adc can be obtained from the battery charger using the front panel AMPERES control. In the battery charging modes, the output current is regulated to within $\pm 5\%$ ± 50 mAdc of the setting of the AMPERES control for all settings greater than 00.10 Adc. Full output power, 360 watts, is available at voltage levels from 30 Vdc to 45 Vdc. Temperature stability of the output current is, typically, 0.01% per °C or better.

TABLE 2.
PERFORMANCE DATA

Parameter	Required Performance	Realized Performance	Units
Continuous Dc Input Voltage Range (For Full Output)	22 - 40	22 - 40	Dc Volts
Transient Dc Input Voltage Range (Operating or Nonoperating)	0 - 80	0 - 80	Dc Volts
Output Current Adjustment Range (All Continuous Input Voltages)	0.1 - 12	0.1 - 12	Dc Amperes
Output Voltage Compliance Range (0 Adc - 12 Adc Output; All Continuous Input Voltages)	6 - 44	5 - 45	Dc Volts
Transition or Cutoff Voltage Adjustment Range (0 Adc - 12 Adc Output; All Continuous Input Voltages)	6.75 - 37	6 - 45	Dc Volts
Maximum Timed Interval	15	15.9	Hours
Dc Power Efficiency (30 Vdc - 12 Adc Output; 28 Vdc Input)	70	80	Percent
Current Regulation (0 Vdc - 45 Vdc, 0.1 Adc - 12 Adc Output; All Continuous Inputs)	<u>+5</u>	<u>+5</u>	Percent
Voltage Accuracy (6 Vdc - 45 Vdc, - Adc - 12 Adc Output; All Continuous Inputs)	+0, -2	+0, -2	Percent
TIME INTERVAL Accuracy (1 Hour - 15.9 Hours; All Outputs; All Continuous Inputs)	-	<u>+5</u>	Percent

TABLE 2.
(Continued)

PERFORMANCE DATA

Parameter	Required Performance	Realized Performance	Units
Internal Transient Control [MIL-STD-1281 (EL)]	Yes	Yes	-
Operating Temperature Range for Full Power	-50 to +154	-50 to +154	°F
Short-Circuit Protection	Yes	Yes	-
Output Overvoltage Protection	No	Yes	-
Output Polarity Protection	Yes	Yes	-
Battery Discharge Protection	Yes	Yes	-
Input Undervoltage and Over- voltage Protection	Yes	Yes	-
Input Reverse Polarity Protection	Yes	Yes	-
Negative Resistance Stabilization	No	Yes	-
Volume of Dc Battery Charger Configuration	1,000	980	CU.IN.
Weight of Dc Battery Charger Configuration	30	31.5	Pounds

2.4 Output Voltage

The output voltage transition level can be set anywhere in the range 0 - 45 Vdc using the VOLTS control. The accuracy of the output voltage is $\pm 0, -2\%$ of the setting of the VOLTS control for settings between 6 and 45 volts for all continuous input voltages listed above and for all load currents. The temperature stability of the transition voltage is 0.002% per °C or better.

2.5 Time Interval

The duration of timed battery charging sequences is determined by the setting of the HOURS control. The accuracy of time intervals is $\pm 5\%$ of the setting of the HOURS control for all settings from 01.0 hours to 15.9 hours. Temperature stability of the time interval is .02% per °C or better.

2.6 Power Efficiency

The power efficiency of the dc battery charger module measure 80% - 85% for output currents in the range 10 Adc - 12 Adc and for output voltages in the range 22 Vdc - 40 Vdc. An efficiency of 82.9% was measured on a test unit with an input voltage of 28 Vdc and with an output voltage of 24 Vdc at 12 Adc 288 watts). This unit measured 84.2% efficient with a 45 Vdc output at 9 Adc (395 watts).

2.7 Protection

Several protective features are provided which prevent damage to the battery charger and to the battery in the event of fault or stand by conditions.

Short-circuit protection is provided at the output so that no more than 13 Adc output current can be obtained from the output terminals in the event of an output short-circuit. A short-circuit or overload condition cannot damage the battery charger because the current levels in the power handling circuit are limited under all conditions of operation. The output current under short-circuit or overload conditions is determined by the setting of the AMPERES control.

Output overvoltage protection is provided to prevent high output voltages in the event of an output open circuit in one of the battery charging modes. The overvoltage limiting level is 45 Vdc.

Output polarity protection is provided to prevent damage to the battery charger in the event of a reverse battery connection at the output. When the battery charger is in active operation in any mode, the application of a reverse polarity battery causes the POWER circuit breaker to trip off; the battery charger is not damaged.

The design of the battery charger is such that a battery preset at the output will not be discharged if the input power to the battery charger is removed or if the battery charger is in the charge-over condition. A current of only 1 mA_{dc} is drawn from the battery under worst case conditions. This prevents accidental discharge of a previously charged battery through the battery charger.

Continuous input under voltages cannot damage the battery charger. Circuits within the battery charger are designed to withstand under-voltages indefinitely.

Application of input voltages in excess of 40 V_{dc} inhibits operation of the battery charger. This reduces the peak voltage levels within the battery charger allowing the input voltage transients up to 80 V_{dc} to be applied without causing damage. The battery charger automatically resume normal operation when the input voltage transient subsides.

Input reverse polarity conditions cause the POWER circuit breaker of the battery charger to trip off. The battery charger cannot be damaged by an input reverse polarity condition.

A negative-resistance stabilization network is incorporated into the battery charger to prevent spurious oscillations at the input due to reactive power sources. Due to its high power efficiency, the battery charger maintains a constant input power characteristic. As a result, input current to the battery charger decreases as the input voltage to the battery charger is increased causing an incremental negative input resistance. This negative resistance in conjunction with reactive power sources can result in oscillations at the input of the battery charger. To prevent such oscillations, a negative-resistance stabilization network is incorporated into the battery charger.

2.8 Internal Transient Control

The circuit designs used within the battery charger comply with the requirements of MIL-STD-1281(EL) entitled, "Internal Transient Control for Solid State Power Supplies." All solid-state components used within the unit are operated within specified voltage, current and power ratings. This is true under steady-state conditions, under all transient input conditions, and under all specified fault conditions on the input and output terminals.

Nonpolar metallized polycarbonate and metallized Mylar capacitors are used as the primary capacitance energy storage elements for the high-frequency power handling circuits used within the battery charger. These capacitors are used in preference to polarized capacitors such as tantalum or aluminum oxide types because of their capability to handle large steady-state ripple current levels reliably, and because of their temperature capability (125°C).

2.9 Size and Weight

The dimensions of the PP-4126()/U dc Battery Charger are 11.25 inches high, 11.25 inches wide, and 7.75 inches long. This results in a volume of 980 cubic inches. The weight of the unit is approximately 31.5 pounds.

3. ELECTRICAL DESIGN

3.1 General

The PP4126()/U Battery Charger is a modularized switching power processor that converts an unregulated 22-40 Vdc input into a regulated output current which may be adjusted from 0.1 Adc to 12.0 Adc. The output current is regulated into output voltages ranging from 6-45 Vdc. The internal design of the battery charger is arranged according to circuit modules or assemblies. The battery charger contains input and output circuits, EMI filters (A5 and A6), a power processing circuit (A4), a VOLTS control circuit (A1), an AMPERES control circuit (A2), and an HOURS control circuit (A3). A simplified block diagram of the battery charger is shown in Figure 3. Each replaceable module in the battery charger is represented in this diagram. Detailed schematic diagrams of each of the modules are given in Figures 5 through 10. The overall module schematic interconnection diagram is shown in Figure 4.

The design and functions of the battery charger internal modules are discussed in this chapter. Discussions are organized in accordance with the modular breakdown of the battery charger.

3.2 Input Circuits

Input power is applied through Connector J1 to the ON/OFF power Circuit Breaker CB2, to the POWER indicator lamp, and through EMI Filters FL3 contained in Assemblies A6 and A5 to the power handling Circuit A4. The EMI filters prevent the high frequency switching current generated within the power handling circuits from escaping to the input power line. The voltage applied to the POWER indicator lamp is regulated by Resistor R1 and Zener Diode CR1. Circuit Breaker CB2 (ON/OFF) protects the battery charger by tripping off whenever the input current exceeds 15 amperes. (This circuit breaker also trips off whenever the output current exceeds 25 amps. Refer to the output circuit description.)

3.3 Output Circuits

The output circuits transfer the output current from the power handling circuits to output Connector J2, these circuits also provide a sensing voltage signal from Connector J2 to the VOLTS Logic A1. EMI Filters FL2, FL4, FL5, and part of Assembly A5 attenuate the high frequency switching current generated within the power handling circuits. Circuit Breaker CB2 (ON/OFF) trips off and opens the output power line, sensing voltage line, and the input power line when more than 25 amperes is drawn from the output of the battery charger. Circuit Breaker CB1 (RUN/CHARGE OVER) is controlled by the output of HOURS Logic A3. A relay trip signal from the HOURS logic causes this circuit breaker to trip to the CHARGE OVER position whenever a battery charging cycle is

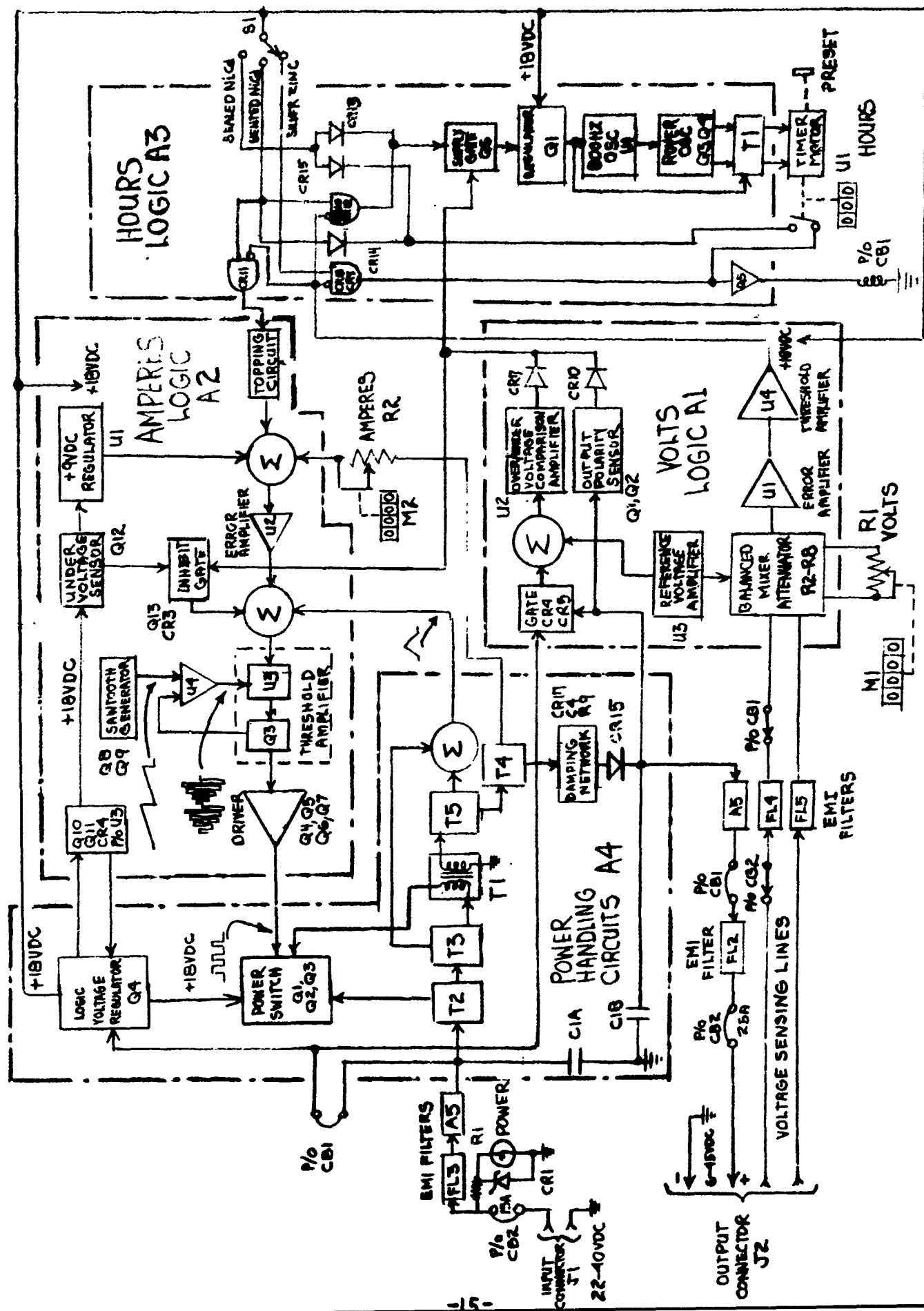


Figure 3. Battery Charger, PP-1126C/U Simplified Circuit
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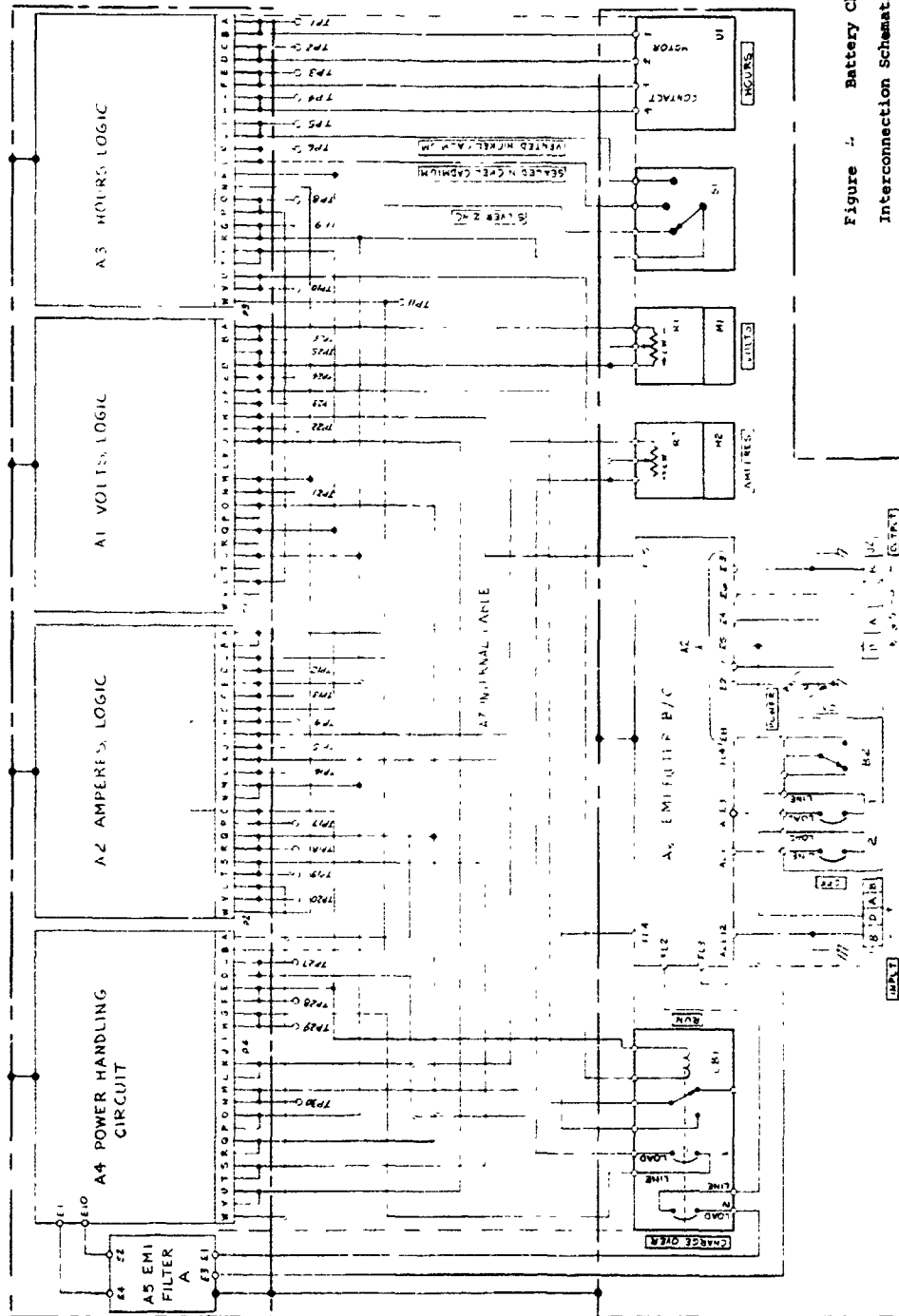
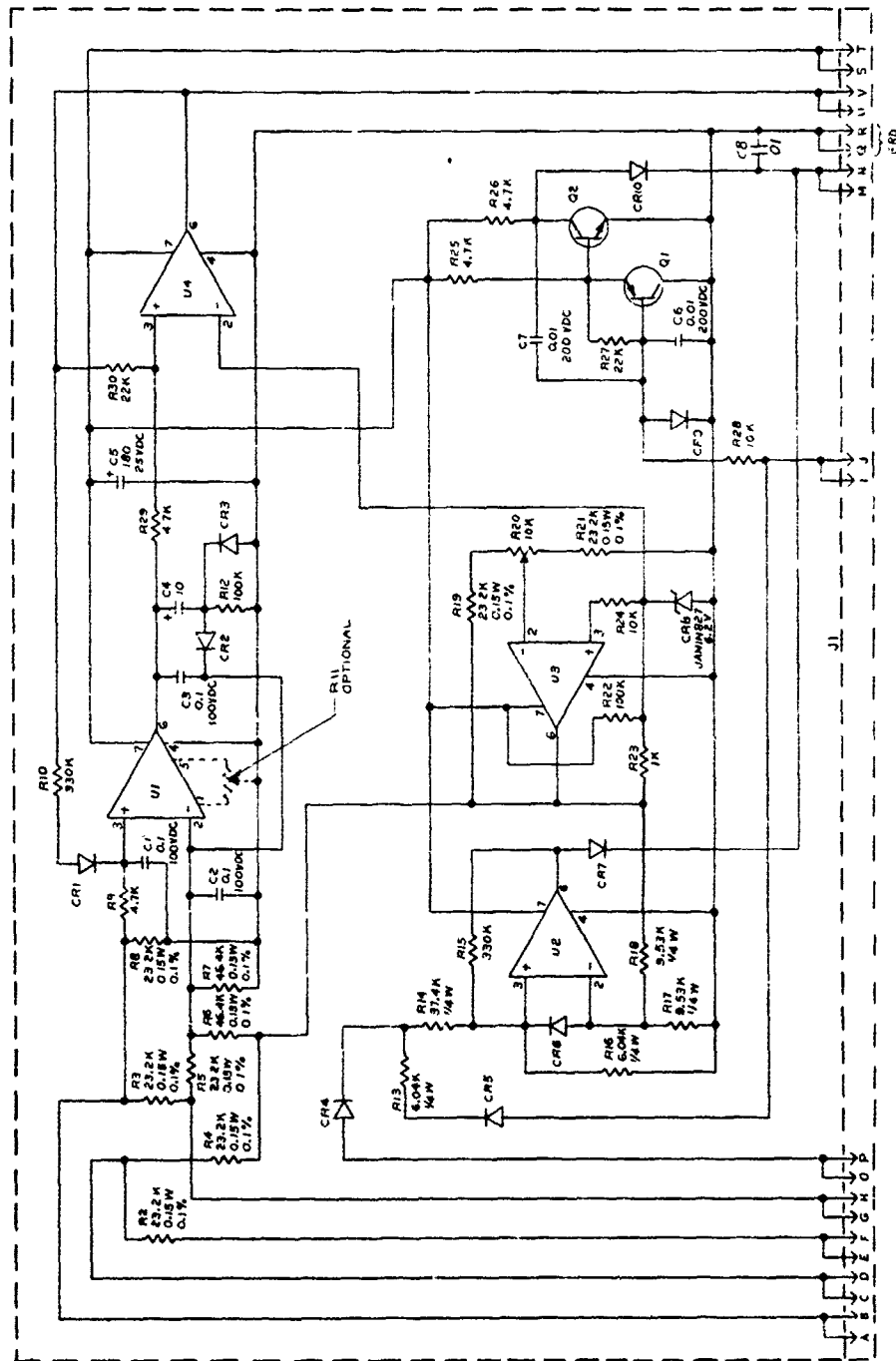
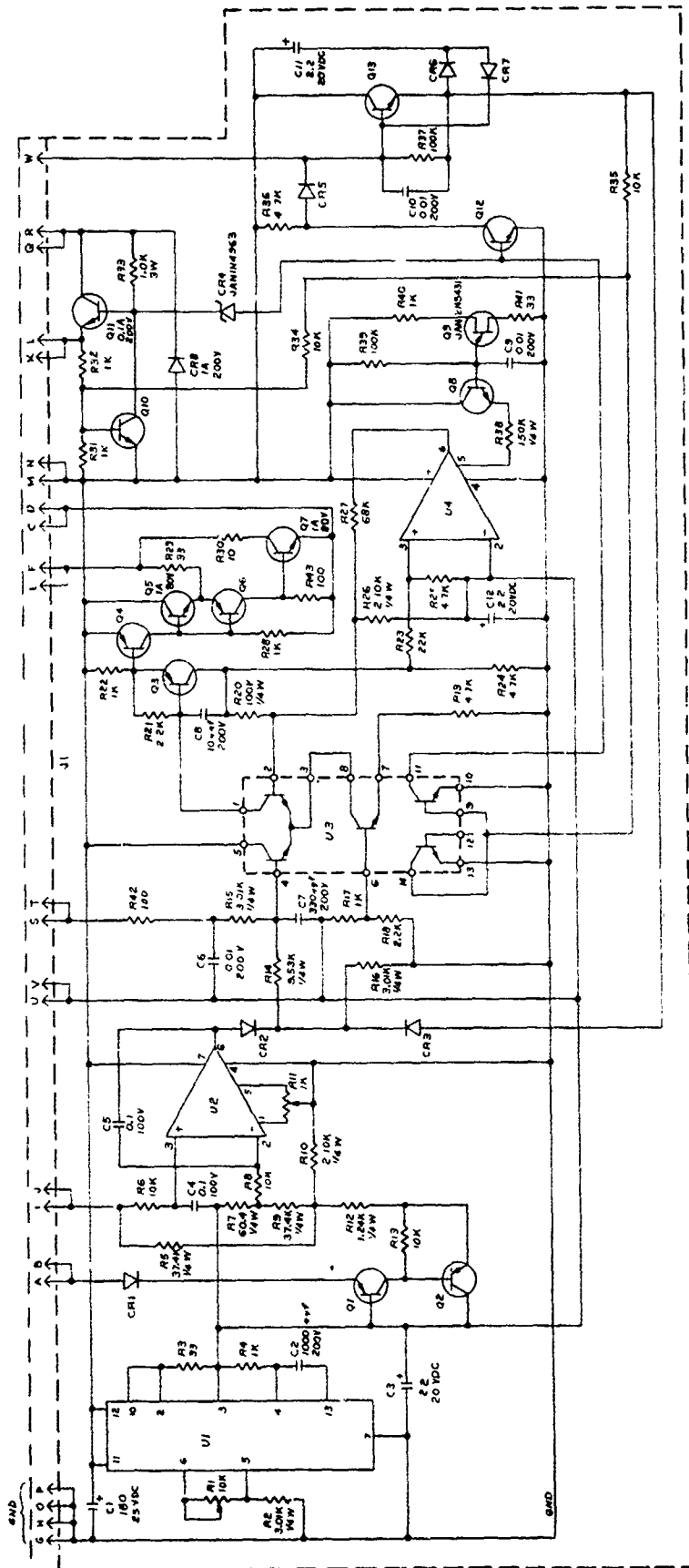


Figure 1. Battery Charger Interconnection Schematic Diagram



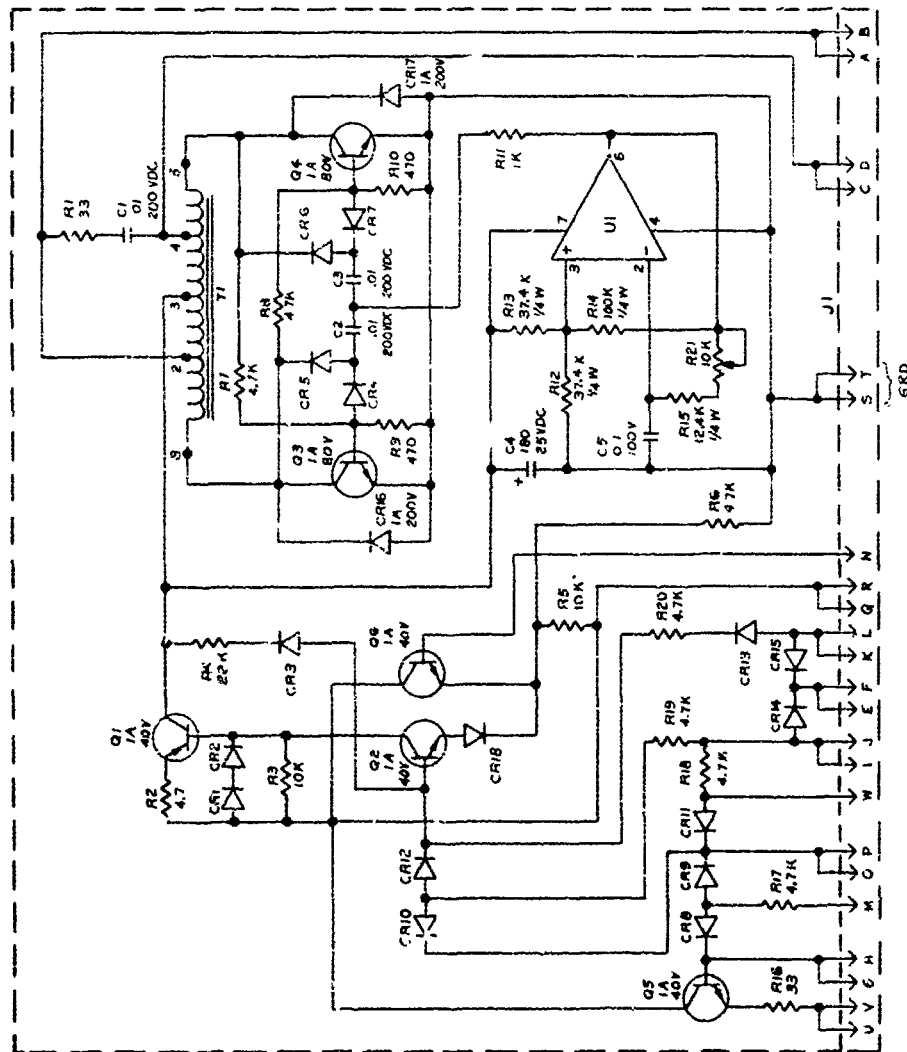
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RESISTORS ARE IN OHMS 1/2 W
CAPACITORS ARE IN MICROFARADS
TRANSISTORS ARE 1A, 40V
DIODES ARE JAN1M4148

Figure 1. Volts Logic P.C. Board
(A1) Schematic Diagram



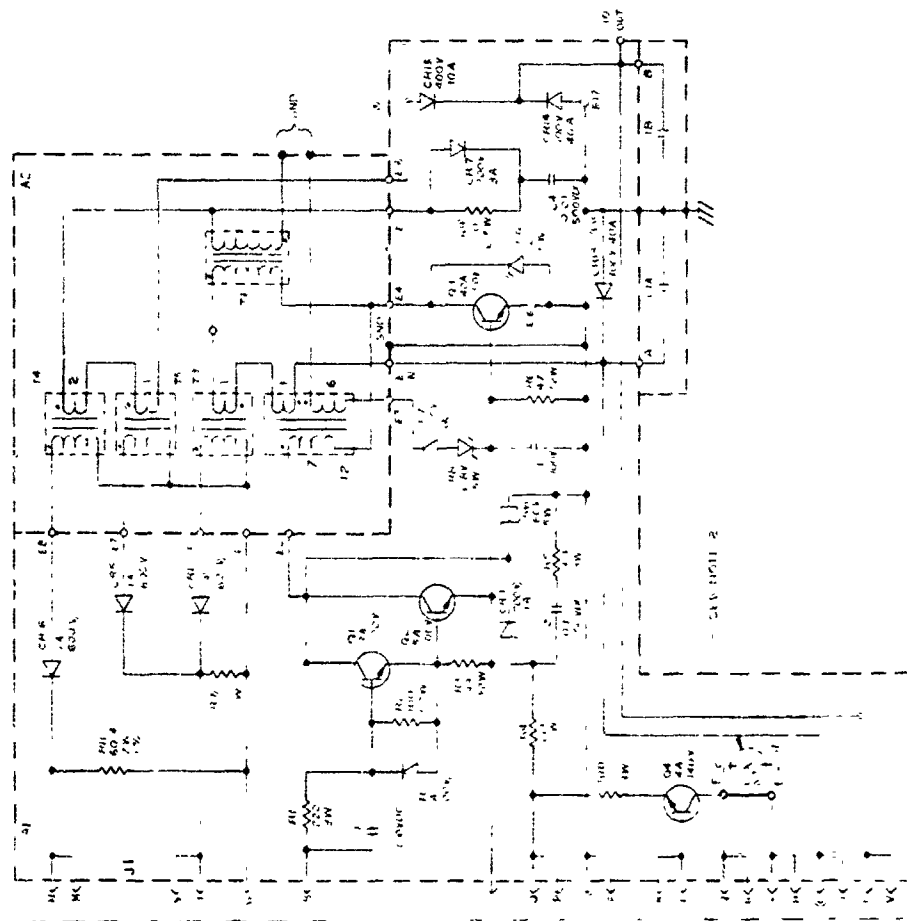
NOTES:
 1. UNLESS OTHERWISE SPECIFIED:
 RESISTORS ARE IN OHMS, 1/2 W
 CAPACITORS ARE IN MICROFARADS
 TRANSISTORS ARE 1A, 40 V
 DIODES ARE JAN1N453

Figure . Ampere Logic P.C. Board
 (A2) Schematic Diagram



UNLESS OTHERWISE SPECIFIED:
 RESISTANCE IS IN OHMS, 1/2 W
 CAPACITORS ARE IN MICROFARADS
 DIODES ARE JAN 1N4148

Figure 7. House Logic P.C. Board
 (A3) Schematic Diagram



NOTE:
1. UNLESS OTHERWISE SPECIFIED,
RESISTORS ARE IN OHMS,
CAPACITORS ARE IN
MICROFARADS
2. OPTIONAL THERMAL SWITCH
MAY BE USED TO PROTECT
TRANSISTORS FROM
OVERHEATING WHEN
USED WITH THE 100V
WIRE WOUND RESISTOR

Figure Power Handling Circuit
(A4) Schematic Diagram

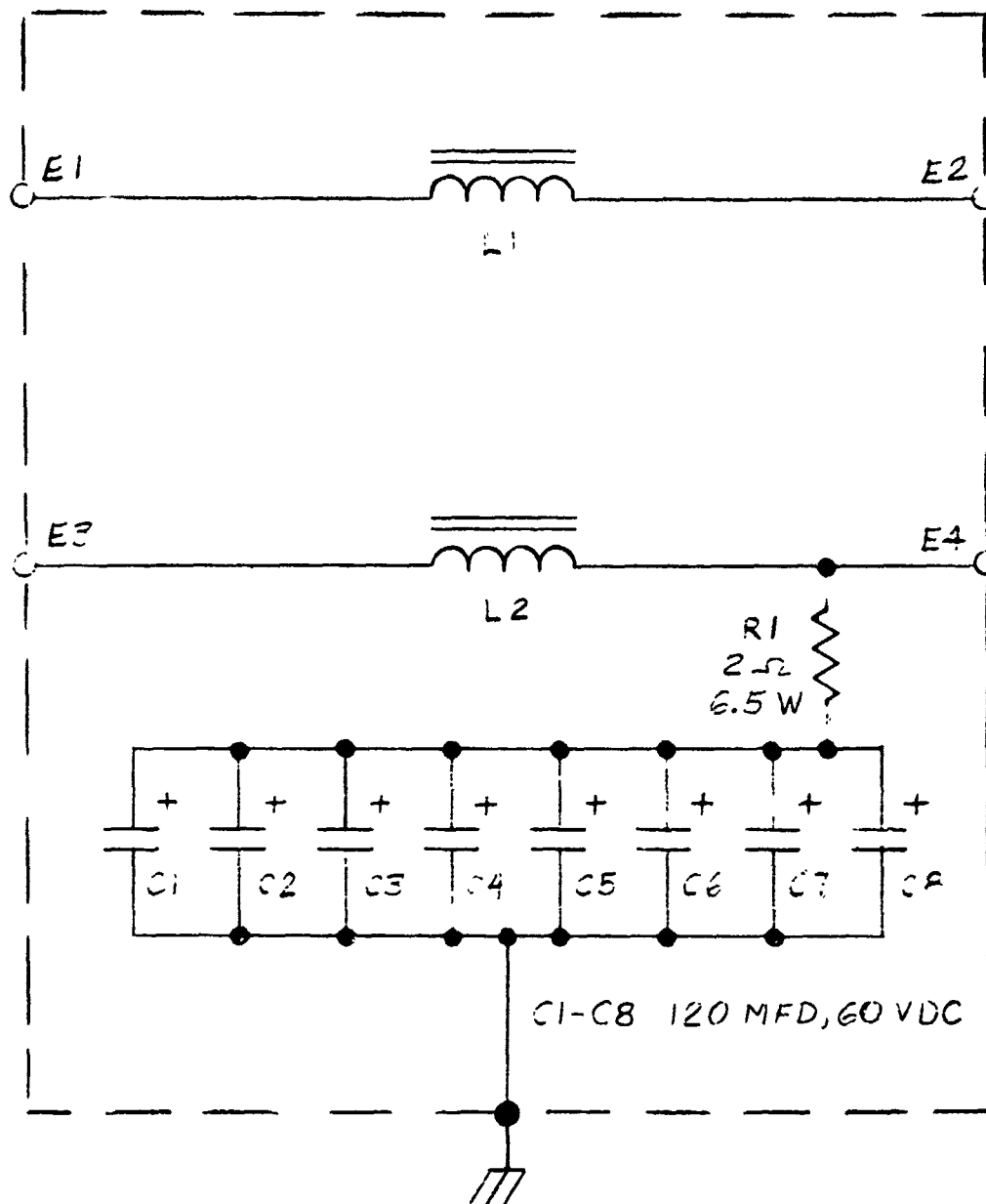


Figure 4. EMI Filter A Assembly
 (A5) Schematic Diagram

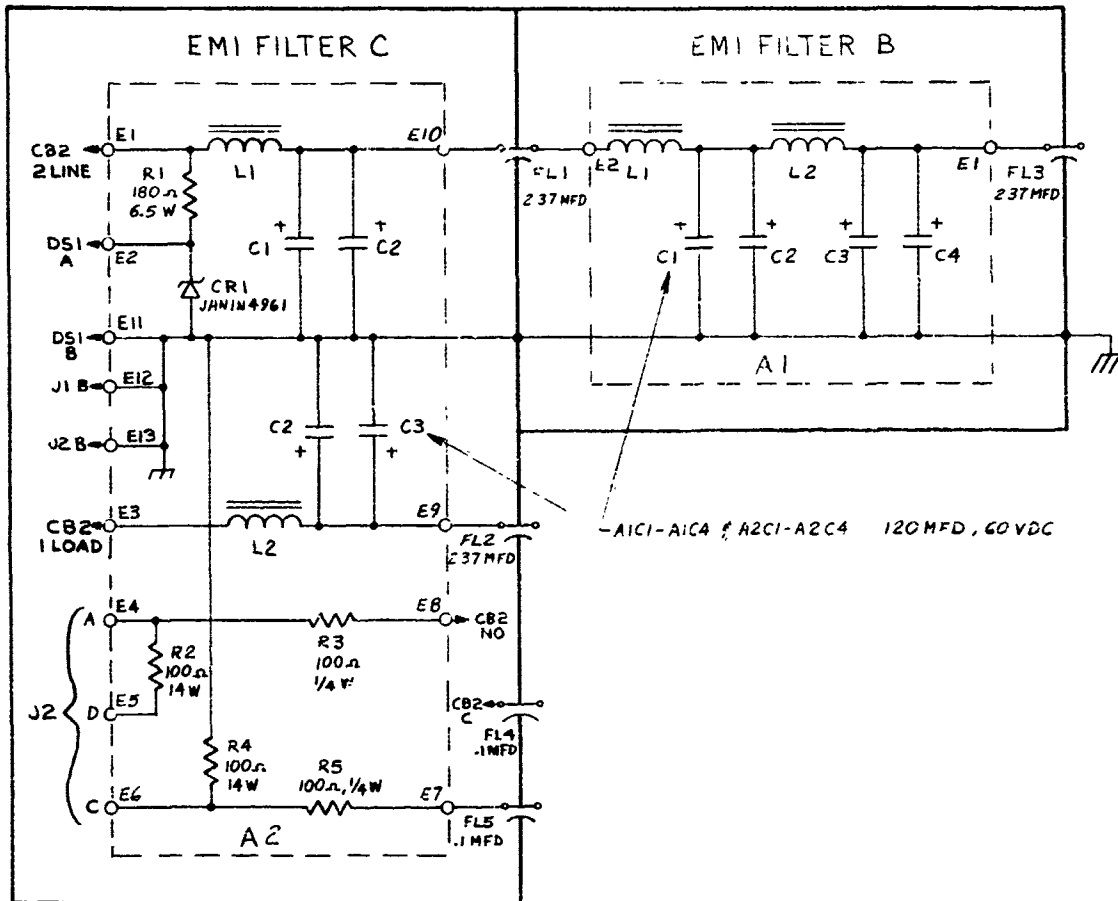


Figure 10 EMI Filter B/C Assembly
(A6) Schematic Diagram

concluded. When tripped to the CHARGE OVER position, Circuit Breaker CB1 opens the output connections both the power connection and the sensing connection, to prevent discharge of a battery connected to the output of the battery charger when the battery charger is in the CHARGE OVER condition.

3.4 Power Handling Circuit (A4)

The power handling circuits derive a regulated output current ranging from 0.1 Adc to 12.0 Adc from the unregulated input power provided to the battery charger. The power handling circuit also provides a regulated +18 Vdc to power the battery charger logic circuits. Additionally, current and voltage sensing signals obtained in the power handling circuit serve as feedback signals for the AMPERES logic and the VOLTS logic circuits. The AMPERES logic, Assembly A2 to be discussed below, provides signals which actuate and control the power handling circuit.

3.4.1 +18 Vdc Logic Power Circuits

The unregulated input voltage applied to the battery charger passes through EMI Filter A5 and through RUN/CHARGE OVER Circuit Breaker CB1. This unregulated voltage is applied to logic voltage regulator Transistor A4Q4 and to the voltage sensing gate in the VOLTS Logic A1, (see below). Circuit Breaker CB1 is closed when it is in RUN position. When Circuit Breaker CB1 trips to the CHARGE OVER position, the battery charger is disabled because the voltage supplied to Transistor A4Q4 is removed causing the +18 Vdc logic voltage to turn off. This condition occurs whenever a charging cycle is completed or whenever Circuit Breaker CB1 is manually indexed to the CHARGE OVER position. The complete logic voltage regulating circuit consists of Transistor A4Q4 in the power handling circuit assembly and Components A2Q10, A2Q11, A2U3 (9,10, and 11), Zener Diode A2CR4). All components except for Transistor A4Q4 are located on the AMPERES logic Assembly A2. Transistor A4Q4 is a series regulator, JAN 2N3442, operating in a linear regulating condition. This transistor absorbs input voltage exceeding the desired +18 Vdc logic voltage level. The transistor is mounted on a heat sink which is part of the power handling circuit. Referring to Assembly A2, transistors in integrated Circuit A2U3 and Zener Diode A2CR4 provide feedback and reference voltages to Transistor A2Q11. Transistor A2Q11 controls current flow through Transistor A4Q4, thereby regulating the logic power. Transistor A2Q10 limits current flow through Transistor A4Q4 by cutting off Transistor A2Q11. This current limiting action occurs whenever voltage drops across Resistor A4R10 exceeds approximately 0.7 Vdc. Resistor A4R10 is a two-ohm resistor; therefore, current flow is restricted to the maximum of 0.35 Adc.

3.4.2 Main Power Handling Circuits

The unregulated input voltage from EMI filter A5 is applied to filter Capacitor A4C1A on Assembly A4. This voltage passes through

windings on Transformers A4T1, A4T2, and A4T3 reaching the collectors of Transistors A4Q1, A4Q2, and A4Q3. These transistors function as a power switch, controlling current flow and voltage excitation to the transformers. Little power is dissipated in the power switching transistors since they fluctuate between a conducting condition where they have a low voltage drop and a nonconducting condition where they have virtually no current flow. Current pulses pass through the current switching transistors at a rate ranging from 15 kHz to 25 kHz. These current pulses are composed of ac and dc current components. The ac current components are supplied primarily from Capacitor A4C1A which serves as an energy storage capacitor. Capacitor A4C1A is a 160 mfd unit using metallized polycarbonate foil to provide a high current capacity.

The power switching transistors are actuated by positive going pulses which are supplied from the AMPERES logic Assembly A2. The power switching transistors conduct for the duration of the positive going pulses drawing current from Capacitor A4C1A through Transforms A4T1, A4T2, and A4 T3. Transformer A4T1 is the main power handling transformer. Transformer A4T2 is a current fed drive transformer. Transformer A4T3 is a current fed current sensing transformer. Transformer A4T1 is a fly-back transformer designed to provide inductive energy storage. This transformer utilizes powdered molybdenum permalloy core material and litz wire windings to obtain efficient high frequency operation. When the power switching transistors conduct, current flows from Capacitor A4C1A through the primary winding of Transformer A4T1. Energy storage in the field of Transformer A4T1, therefore, increases. When the power switching transistors cut off, revert to a nonconducting state, energy stored in the field of Transformer A4T1 is released to the secondary winding resulting in current flow through output portion of the power handling circuit. The secondary current flow passes through Transformers A4T4 and A4T5 and through Rectifier A4CR15. This secondary current flow is composed of current pulses having both dc and ac components. The ac current components are largely absorbed by Capacitor A4C1B. The dc current component is coupled through EMI Filter A6FL2, through EMI Filter A5 and through Circuit Breakers CB1 (RUN/CHARGE OVER) and CB2 (ON/OFF) to output Connector J2. The damping network composed of Rectifier A4CR17, Capacitor A4C4, and Resistor A4R9 attenuates voltage transients developed on the windings of Transformer A4T1 during switching transitions.

As noted above, Transformer A4T2 is a current-fed driver transformer. This transformer provides feedback drive current proportional to the current flow through the power switching transistors. The feedback current is used to provide an efficient source of current to saturate the main power switch Transistor, A4Q3, when the power switching transistors are in a conducting state. This drive current is provided from the seven turn windings of Transformer A4T2. In addition, feedback current provided from the six turn winding of Transformer A4T2 provides reverse current flow to the base of Transistor A4Q3 to affect a rapid transition from the saturated conducting state to the nonconducting state. This

reverse current flow reduces power dissipation during the turn-off switching interval permitting Transistor A4Q3 to operate at a high pulse repetition rate without experiencing excessive dissipation. Transformer A4T2 is designed with winding turns ratios which provide Transistor A4Q3 with forced gain operation at a current gain factor of approximately six. Forced gain operation is maintained regardless of current level and is maintained during conduction times and during ON/OFF transition times when the base current to Transistor A4Q3 is reversed.

Current sensing Transformer A4T3 provides a secondary current flow via Diode A4CR11 to Resistor A4R7. This secondary current flow is proportional to current flow to the primary windings of Transformer A4T1. Consequently, the voltage produced on Resistor A4R7 is proportional to current flow through the primary winding of Transformer T1 during the time that the power switching transistors are passing current through the primary winding of Transformer A4T1. When the power switching transistors are in a nonconducting state, current flow exists in the secondary winding of Transformer A4T1. Secondary current flow from Transformer A4T1 passes through current-fed Transformer A4T5. A resultant secondary current flow from Transformer A4T5 passes through Rectifier A4CR5 to Resistor A4R7. This, again, produces a voltage on Resistor A4R7 which is proportional to the secondary current flow from Transformer A4T1. Since the turns ratio of Transformer A4T1 is 1:1, the relationship between primary and secondary current flow in Transformer A4T1 is identical in relation to the field energy of Transformer A4T1. Consequently, Transformers A4T3 and A4T5 use identical turns ratios, 1:200, so that secondary current flow to Resistor A4R7 is equally weighted. The value of Resistor A4R7 is ten ohms; this results in a relationship between the voltage developed on Resistor A4R7 and the field energy in Transformer A4T1, or since the field energy is related to current flow through the windings in Transformer A4T1, a relationship exists between the voltage on Resistor A4R7 and current flow through the windings of Transformer A4T1. The sensitivity relationship is 0.05 volts per ampere. Thus, one volt is developed across Resistor A4R7 when 20 amperes of current circulates through the windings of Transformer A4T1. The current sensing signal developed on Resistor A4R7 is a continuous measure of total current flow through Transformer A4T1. In normal operation, the current sensing signal is composed of a dc component and a superimposed sawtooth ac signal. The current sensing signal derived on Resistor A4R7 is the primary feedback signal to the AMPERES logic circuitry (A2). This signal actuates operation of the switching control circuitry. The feedback signal from Resistor A4R7 is instrumental in determining current limiting which instantaneously restricts current flow through the power switching transistors under all operating conditions. The instantaneous current limiting is essential since it insures that the main power switching transistors cannot experience excessive current flow under any operating condition.

An additional current-fed Transformer, A4T4, provides a proportional current flow through Diode A4CR16 to Resistor A4R11. As a result,

voltage pulses appear across Resistor A4R11 proportional to the secondary current flow from Transformer A4T1. The turns ratio of Transformer A4T4 is 2:200, and the value of Resistor R11 is 60.4 ohms. This results in a current sensing sensitivity across Resistor A4R11 of 0.6 volts across Resistor A4R11 per ampere current flow through the secondary windings of Transformer A4T1. In other words, a 20-ampere current level at the secondary of Transformer A4T1 results in a 12-volt signal across Resistor A4R11. This relatively high amplitude current sensing signal is used as the feedback signal for output current regulating circuitry located within the AMPERES logic Circuit, (A2). The voltage signal developed on Resistor A4R11 is connected to the AMPERES logic circuitry via AMPERES control potentiometer R2. This feedback circuit is designed such that the dc average current flow through Potentiometer R2 is constant regardless of the value of R2. The voltage level at the output of Potentiometer R2 is virtual ground potential remaining constant at all times. Therefore, the voltage on the A4R11 side of Resistor R2 must be proportional to the resistance of R2 if the constant current flow constraint through Potentiometer R2 is to be maintained. Therefore, the voltage developed on Resistor A4R11 is proportional to the value of R2. The relationship between dc voltage developed across Resistor R11 and the setting of the AMPERES control, R2, is: 0.144 volts/kohms. Taking into account the relationship between current flow from Transformer A4T1 and voltage developed on Resistor A4R11, the relationship between the setting of the AMPERES control and output current from the power handling circuit can be derived. The relationship is 0.24 amperes/kohm. Controlling the dc signal level developed on Resistor A4R11, therefore, controls the dc current flow at the secondary of Transformer A4T1. Since there are no shunt paths for dc current flow between the power handling circuits and the output of the battery charger, a regulated output current flow is obtained from the battery charger by regulating the dc current flow within the power handling circuits.

Transformers A4 (T2, T3, T4, and T5) are composed of simple ferrite cores with bobbin-wound windings. All of the transformers are included in a single magnetic assembly which is a portion of the power handling Circuit, A4.

In order to provide reverse polarity protection, two power diodes are included in the power handling circuits to produce a low impedance condition if reverse polarity voltages are applied to the battery charger. These rectifiers are A4CR13 and A4CR14. The application of a reverse polarity to either the input or the output of the battery charger results in a current surge through the input Connector, J1 or the output Connector, J2. This, in turn, causes the power Circuit Breaker, CB2, to trip off.

3.5 AMPERES Logic Circuits (A2)

The basic function of the AMPERES logic circuitry is to control instantaneous current levels within the power handling circuit (A4) and to regulate the output dc current flow from the battery charger depending

upon the setting of the AMPERES Potentiometer R2, located on the front panel of the battery charger. In addition, linear regulating circuits are contained on the AMPERES logic circuit to control the +18 Vdc logic power level and to derive a +9 Vdc logic power level. Finally, a gating circuit is including to inhibit battery charger operation in the event of abnormal input supply conditions or reversed output polarity conditions.

3.5.1 Two-State Control Circuits

Instantaneous operation of the power switching transistors in Assembly A4 is controlled by circuitry in the AMPERES logic. The current sensing voltage developed on Resistor A4R7 by Transformers A4T3 and A4T5 is applied to a summing network in the AMPERES logic circuits. The current sensing feedback signal is electronically compared with an error voltage signal developed by Amplifier A2U2. These combined signals actuate a threshold or hysteretic amplifier composed of transistors in monolithic Amplifier A2U3 and Transistor A2Q3. The output signal of the threshold amplifier is a two-state voltage. The two-state voltage is further amplified by driver circuit composed of Transistors A2 (Q4, Q5, Q6, and Q7). The output of the driver circuit actuates the power switching transistors in the power handling circuits. Hysteresis is derived in the threshold amplifier through the use of positive feedback. Referring to the schematic diagram of Assembly A2, Resistor A2R20 provides a fixed amount of positive voltage feedback to Amplifier A2U3. In addition, a variable positive feedback signal is provided to Amplifier A2U3 from a modulated transconductance Amplifier, A2U4. This latter positive feedback signal is modulated with a sawtooth waveform generated by unijunction Transistor A2Q9 and emitter-follower Transistor A2Q8. The variable positive feedback derived via Amplifier A2U4 causes a periodic, 10 Hz, modulation of the hysteresis developed within the threshold amplifier circuit. The modulated hysteresis results in a frequency modulation of the pulse repetition rate within the two-state circuits. Pulse frequency modulation is utilized to disperse the spectral energy content of the two-state pulses over a broad range of frequencies. This avoids concentrating EMI signals at discrete frequencies. Therefore, the task of EMI filtering within the battery charger is made easier.

The basic operation of the two-state circuit is thus derived through the use of Current Controlled Two-State Modulation (CCTSM). The arrangement between the power handling circuit and the AMPERES logic circuit is a feedback controlled, self-oscillating, two-state power processing configuration. The characteristics of Current-Controlled Two-State Modulation are described in more detail in Appendix 1 of this report. The use of CCTSM provides instantaneous current limiting for the power switching transistors under all static and dynamic operating conditions. In addition, CCTSM controls the fly-back current level in fly-back Transformer A4T1 in a stable fashion. Therefore, current levels in the transformer are controlled in a predictable fashion under every operating condition.

3.5.2 Output Current Regulating Circuitry

As noted in previous discussions, the output dc current flow from the battery charger is regulated by the AMPERES logic circuit simply by holding the dc voltage developed across current sensing Resistor R11 at a constant value. Amplifier A2U2 in the AMPERES logic circuit carries out this function. The current feedback signal is applied to a resistive summing network at Amplifier A2U2. A reference voltage proportional to the +9 Vdc level generated by monolithic Regulator A2U1 is applied to Amplifier A2U2 via Resistor A2R5. Amplifier A2U2 provides an amplified error signal at its output depending on the difference between the reference signal and the dc value of the current feedback signal. The amplified error signal controls operation of the CCTSM circuitry described above. Action of the error Amplifier, A2U2, causes a regulated output current flow to occur from the battery charger. Output current regulation is maintained under all conditions of input voltage from 22 Vdc-40 Vdc and for all output voltages in the range 6 Vdc-45 Vdc.

An additional circuit composed of Transistors A2Q1 and A2Q2 is included in the output current regulating circuit to permit reducing output current flow to 40% of its set value. This provision is used in the vented nickel cadmium battery charging mode to provide a "topping" charging stage. Reduction in the output current flow from the battery charger during the "topping" phase is accomplished by Transistors A2Q1 and A2Q2 simply by reducing the reference signal applied at the input to error Amplifier A2U2.

3.5.3 Linear Voltage Regulating Circuitry

The AMPERES logic circuit includes circuits which control the +18 Vdc logic power level and generate the +9 Vdc regulated logic voltage. As noted above, Transistor A4Q4 regulates the +18 Vdc logic power voltage. Operation of this transistor is controlled by Transistor A2Q11 and Zener Diode A2CR4 in the AMPERES logic. Transistor A2Q10 provides current limiting for the +18 Vdc regulator to prevent damage to Transistor A4Q4 in the event of a short circuited or over loaded logic power condition. Rectifier A2CR8 prevents damage to the logic voltage regulating transistors in the event of a sudden short circuit of the power source. This diode is necessary since otherwise, reverse breakdown may occur in the regulating transistors.

Transistor A2Q12 detects when the +18 Vdc logic power level is in regulation. When abnormally low input voltage levels are applied to the battery charger, the logic power cannot reach the +18 Vdc level. Under such conditions, Transistor A2Q12 inhibits battery charger operation. This inhibiting action via Transistor A2Q13 is discussed below. The two transistors in monolithic Circuit A2U3 provide a reverse bias current to the base of Transistor A2Q12 to prevent spurious operation.

In a +9 Vdc regulated logic voltage a reference signal is derived from monolithic regulator A2U1. This is a standard 723 integrated circuit. The +9 Vdc voltage level serves as a reference for the output current regulation circuitry described above. In addition, the instantaneous current-limiting derived by inherent action of the CCTSM circuit is proportional to this voltage.

3.5.4 Inhibit Gate

An inhibiting signal is provided to the CCTSM circuit from Transistor A2Q13 via Diode A2CR3. Inhibiting circuit prevents battery charger operation in the event of abnormal input or output voltage conditions or when a reverse output polarity condition exists. Inhibiting inputs to Transistor A2Q13 come from Transistor A2Q12 of the AMPERES logic, preventing operation under low input voltage conditions and from the VOLTS Logic (A1) described below to inhibit operation when abnormally high input or output voltage conditions exist on the battery charger and to prevent battery charger operation when reverse output polarity conditions exist. Transistor A2Q13 is connected with Capacitor A2C11 to provide fast-inhibit/slow-enable operation.

3.6 VOLTS Logic Circuit (A1)

The VOLTS logic assembly contains circuits which control the transition voltage point in the battery charger. In addition, protective circuits are provided in this assembly to inhibit operation of the battery charger in the event of excessive input or output voltage levels and when a reverse output voltage polarity is present.

3.6.1 Transition Voltage Control Circuits

An output voltage sensing signal is received by the VOLTS logic circuits. This signal is applied to a balanced resistive summing and attenuating circuit composed of Resistors A1 (R2-R8). The attenuation of this resistive network is controlled by the front panel VOLTS control, Potentiometer R1. A precision reference voltage is applied to the summing network from a reference buffer Amplifier A1U3. The reference voltage developed at the output of Amplifier U3 is adjusted to approximately 11.6 Vdc. This permits the use of a maximum 100 kohm Potentiometer R1 with programming sensitivity of 0.5 Vdc/kohm. The output of Amplifier A1U3 is adjusted by trimming Resistor A1R20. A precision reference Diode, A1CR8, provides the stable input for Amplifier A1U3. When the error signal at the input to Amplifier A1U1 reaches a positive level, that is, the voltage at Pin 3 become greater than the voltage at Pin 2, the output of Amplifier A1U1 at Pin 6 shifts positive. This positive shift is delayed by Capacitors A1C3 and A1C4 in order to avoid spurious operation which would prematurely interrupt the battery charging operation. When the output of Amplifier A1U1 becomes sufficiently positive, an Amplifier A1U4 is actuated to produce a positive voltage at the output

of ALU4. Amplifier ALU4 utilizes positive feedback via Resistor ALR30 to obtain a toggling action. Therefore, the signal developed at the output of ALU4 is a digital signal. This digital signal serves as a major input signal to the logic circuits contained in the HOURS logic circuits discussed below. Positive feedback provided via Resistor ALR10 and Diode ALCR1 latch the output of Amplifier ALU1 positive once the voltage threshold has been reached. As a result, the output voltage from the battery charger must be reduced approximately 10% before the voltage threshold circuits revert to a condition where they permit active battery charger operation.

3.6.2 Protective Circuitry

The input and output voltages of the battery charger are weighted and gated through Diodes ALCR4 and ALCR5. Voltages applied to a summing network that compares them to a reference voltage obtained from reference Amplifier ALU3. Whenever the voltage developed by the summing network is greater than the reference voltage developed by the reference Amplifier ALU3, an input voltage greater than 40 Vdc or output voltage greater than 45 Vdc, the overvoltage comparison Amplifier, ALU2, produces a zero voltage output which is coupled through Diodes Gate ALCR7 to both the AMPERES logic circuit (A2) and the HOURS logic circuit (A3). This overvoltage signal causes the inhibit gate in the AMPERES logic circuit to operate inhibiting operation of the battery charger power handling circuits. The inhibiting signal also inhibits operation of the timing circuits in the HOURS logic so that time spent in an overvoltage condition is not counted as battery charging time. The HOURS logic circuits are discussed in more detail below. The battery charger output voltage polarity is monitored by an output voltage polarity sensing circuit composed of Transistors ALQ1 and ALQ2. Whenever a reverse output voltage polarity condition exists (this may be caused by applying a battery with reversed polarity to the output of the battery charger), the output polarity sensing circuit produces a zero voltage output which passes through Diode Gate ALCR10. The signal passing through Diode ALCR10 again actuates the inhibiting circuitry in the AMPERES logic and also inhibits operation of the timing circuits in the HOURS logic.

3.7 HOURS Logic Assembly (A3)

The HOURS logic circuit accepts digital input signals from the AMPERES logic assembly, the VOLTS logic assembly, the hours timer, and the front panel mode switch. The HOURS logic provides three output functions: it controls the relay tripping RUN/CHARGE OVER circuit breaker, CB1, which terminates the battery charging cycles: it provides a digital control signal to the "topping" circuit, described above, located in the AMPERES logic assembly, it provides a drive signal for the HOURS timer.

3.7.1 Digital Logic Circuits

Silver Zinc Mode.

In the SILVER ZINC mode of operation, when the signal from Amplifier ALU4 of the VOLTS logic is positive, the HOURS logic causes Circuit

Breaker CB1 (RUN/CHARGE OVER) to trip to the CHARGE OVER position terminating active battery charger operation. In this mode, Diodes A3CR8 and A3CR9 and Transistor A3Q5 provide the logic function. Diodes A3CR8 and A3CR9 are connected as a gate requiring positive digital input signals at Terminal M of Assembly A3 from the mode selector switch and at Terminals O/P from Amplifier A1U4.

Vented Nickel Cadmium

In the VENTED NICKEL CADMIUM mode of operation, the signal from Amplifier A1U4 provides a digital indication to the HOURS logic if the output battery voltage is equal to (or in excess of) the set transition voltage point. This causes the timer circuits to operate via a gate composed of Diodes A3CR10 and A3CR12. Additional signals are required at Terminals G/H and I/J of the HOURS logic assembly. The HOURS logic also provides a positive digital signal at terminals I/J enabling the switch in the timer module, HOURS, panel control. The HOURS switch closes when the HOURS indication reaches 00.0 hours. This causes a positive digital to be returned to the HOURS logic circuit at Terminals G/H, actuating Transistor A3Q5 causing Circuit Breaker CB1 to trip to the CHARGE OVER position. Finally, a positive digital signal is provided via a gate composed of Diodes A3CR11 and Resistor A3R18 to actuate the "topping" circuit located in the AMPERES logic assembly. This causes the output current from the battery charger to be reduced to 40% of the value set in the front panel AMPERES control.

Sealed Nickel Cadmium

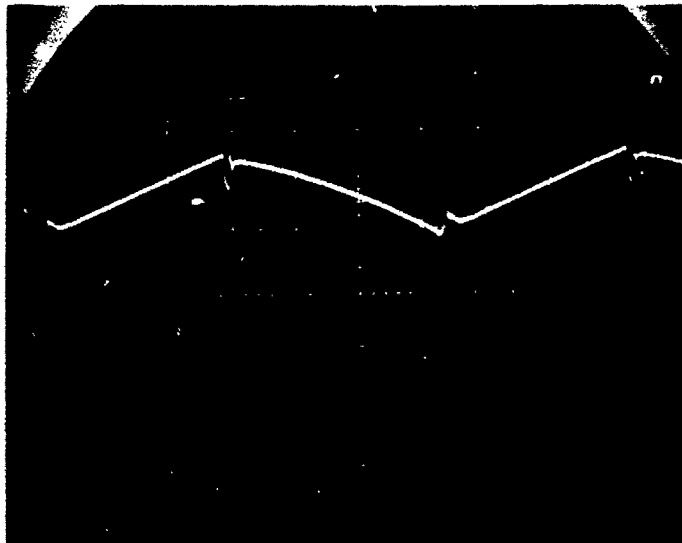
In the SEALED NICKEL CADMIUM mode of operation, the timing circuits are started as soon as the battery charger commences active operation. Diode A3CR13 actuates the timing circuits. A positive digital signal is supplied at the anode of this diode from the mode selector switch. Diode A3CR15 actuates the switch in the timer via Terminals E/F so that when the timing indication reaches 00.0 and the time switch closes, the Circuit Breaker CB1 will trip to the CHARGE OVER position. The timer switch again causes the circuit breaker to switch by returning a positive digital signal to Terminal G/H of the HOURS logic. This actuates Transistor A3Q5 which trips the circuit breaker via a connection from Terminals U/V of the HOURS logic.

3.7.2 Timing Circuits

Operation of the timing circuits is gated on and off by Transistors A3Q1, A3Q2, and A3Q6. The gating function is accomplished simply by causing Transistor A3Q1 to supply power to the timing circuits when timer operation is desired.

Amplifier A3U1 is connected as an 800 Hz square wave oscillator. The square wave developed at the output of Amplifier A3U1 is applied to a toggled Royer oscillator composed of Transistors A3Q3, A3Q4 and Transformer A3T1. The Royer circuit toggles at 400 Hz producing a 26 Vac signal at the output terminals 2 and 4 of Transformer A3T1. This square wave signal is sufficient to drive the timer motor in the HOURS control.

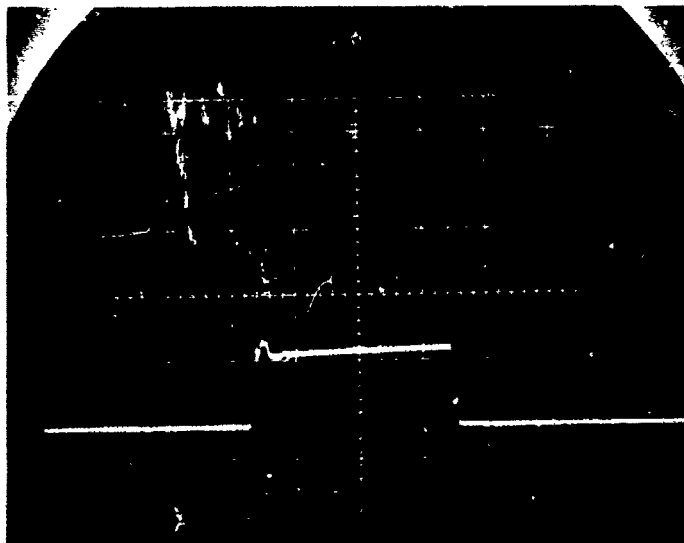
4. WAVEFORMS



Input Voltage Ripple
2 V/Maj. Div.
(28 Vdc Input)

Time - 10 μ S./Maj. Div.

Figure 11.
Ripple Voltage of Input to Power Handling Assembly
(Terminal A of Capacitor C1)

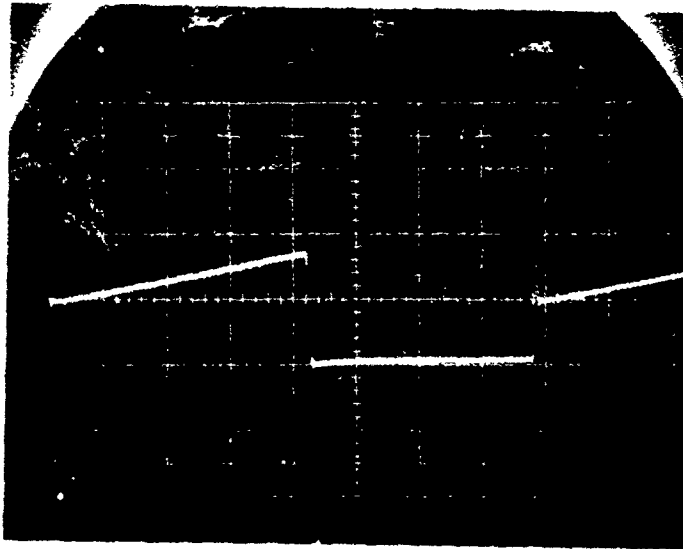


Voltage at Collector
of Power Transistor
A4Q3

50 v/Maj. Div.

Time - 10 μ S./Maj. Div.

Figure 12.
Voltage at Collector of Main Power Switching
Transistor (A4Q3)



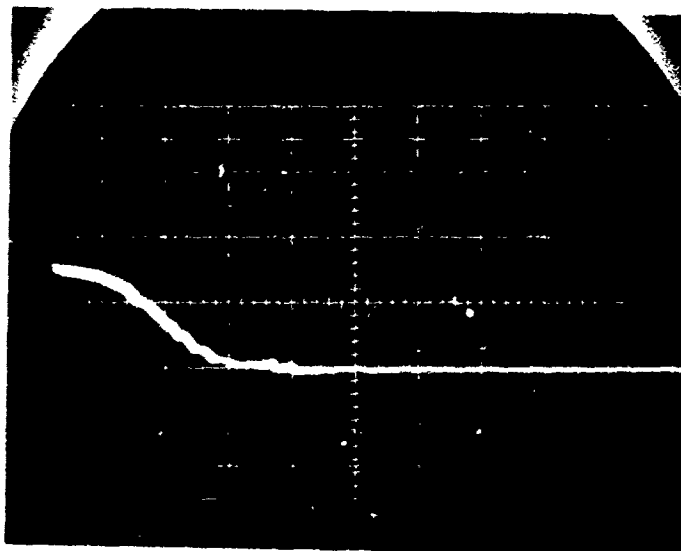
Total Power Switch
Current Flow

20 A/Maj. Div.

0

Time - 10 μ S./Maj. Div.

Figure 13.
Current Flow Through Primary Winding of Fly-Back
Transformer (A4T1)



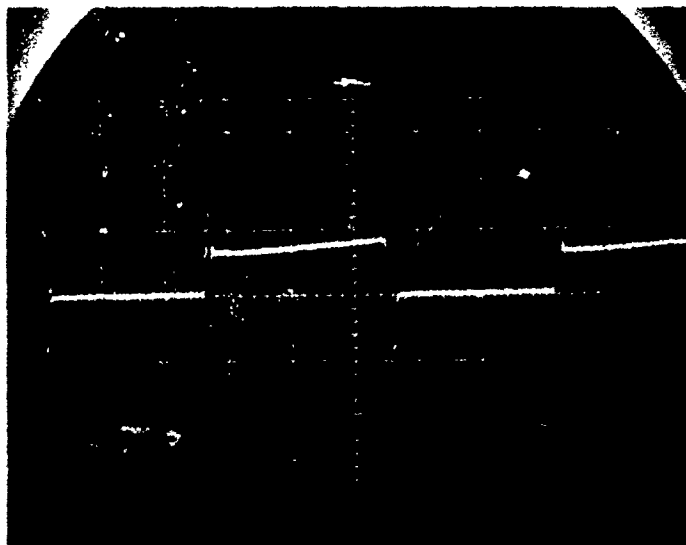
Total Power Switch
Current Flow

20 A/Maj. Div.

0

Time - 200 nS./Maj. Div.

Figure 14.
Fall Time of Current Flow Through Primary Winding
of Fly-Back Transformer (A4T1)

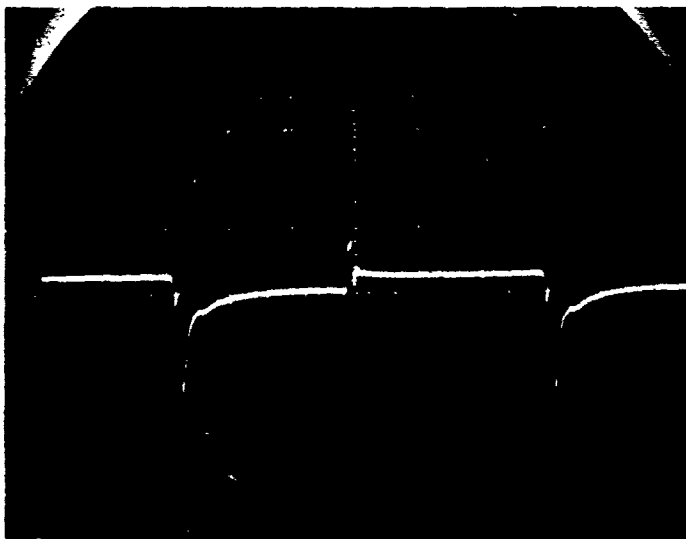


Base Current in Power
Transistor A4Q3

5 A/Maj. Div.

Time - 10 μ S./Maj. Div.

Figure 15.
Base Drive Current in Main Power Transistor (A4Q3)

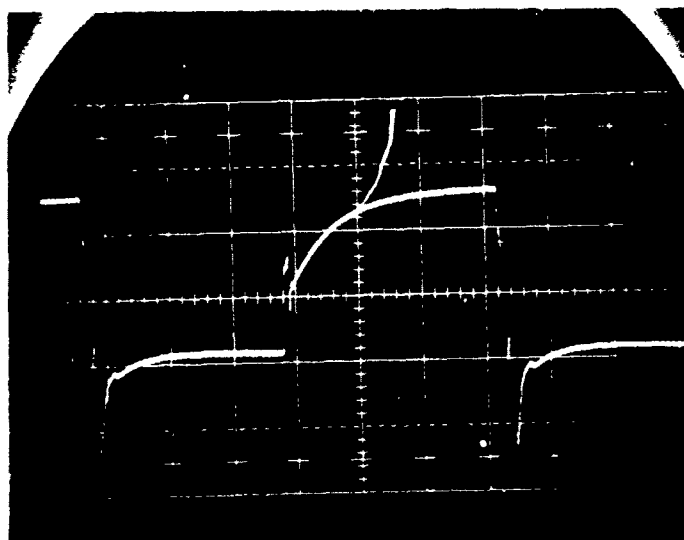


Base Voltage of Power
Transistor A4Q3

5 V/Maj. Div.

Time - 10 μ S./Maj. Div.

Figure 16.
Base Voltage of Main Power Transistor (A4Q3)



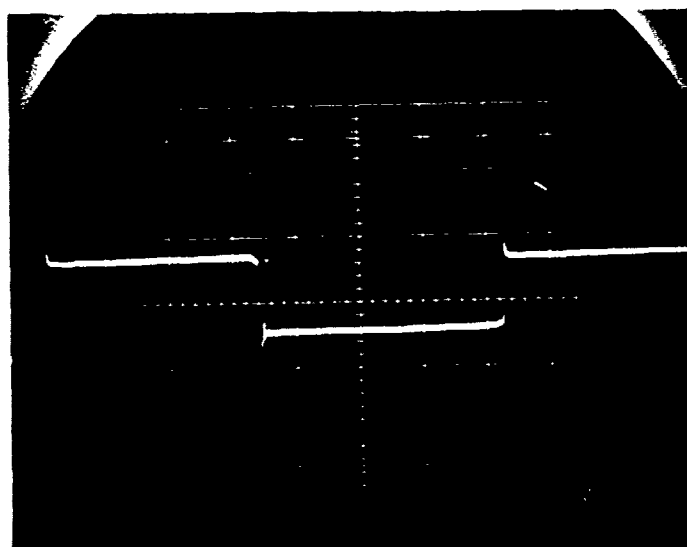
Drive Voltage at
Two-State Input to
Power Handling Module

5 V/Maj. Div.

0

Time - 10 μ S./Maj. Div.

Figure 17.
Drive Voltage at Input to Power Handling Module
(Terminal B of A4)



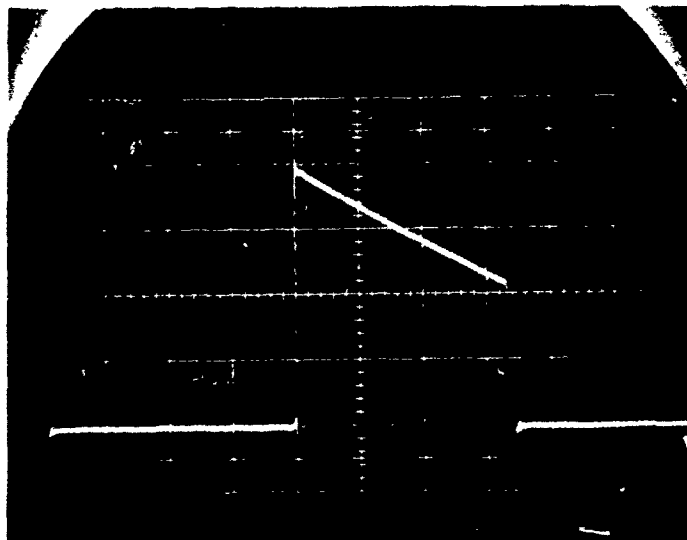
Voltage at Secondary
of Fly-Back Transformer

50 V/Maj. Div.

0

Time - 10 μ S./Maj. Div.

Figure 18.
Voltage Developed at Secondary of Fly-Back Transformer
(A4T1)



Output Current Sensing
Voltage

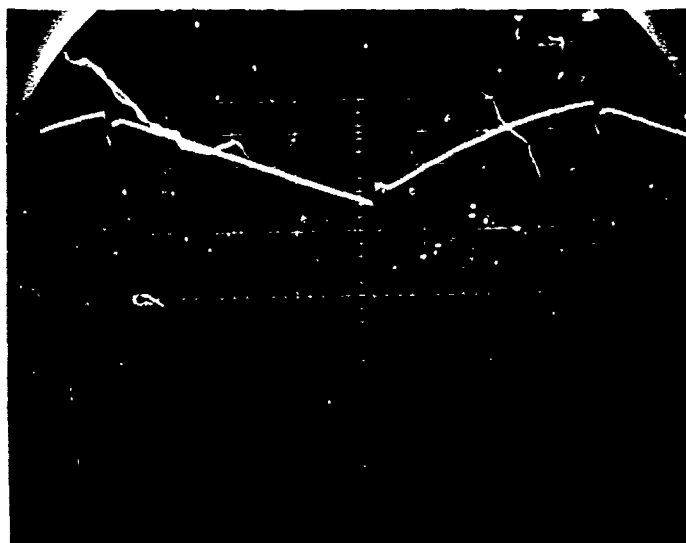
5 V/Maj. Div.

(Corresponds to
8.3 A/Maj. Div.)

0

Time - 10 μ s./Maj. Div.

Figure 19.
Output Current Sensing Signal (Terminals N/M of A4)



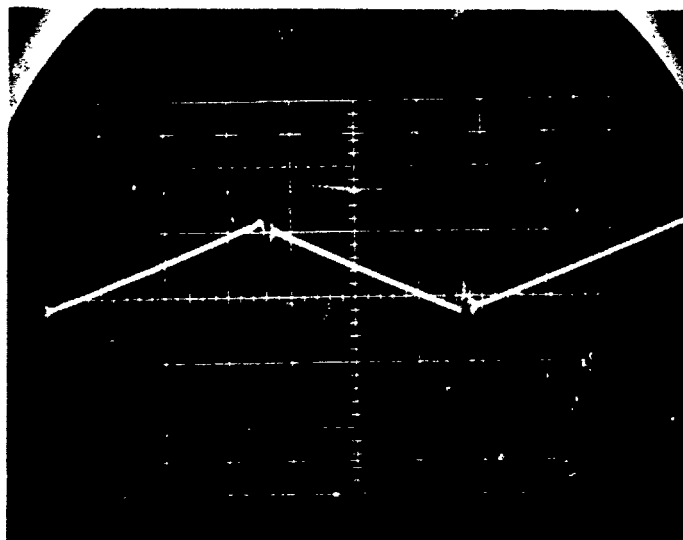
Output Voltage Ripple

2 V/Maj. Div.

(28 Vdc Output)

Time - 10 μ s./Maj. Div.

Figure 20.
Ripple Voltage at Output of Power Handling Assembly
(Terminal B of Capacitor C1)



Total Current
Sensing Voltage

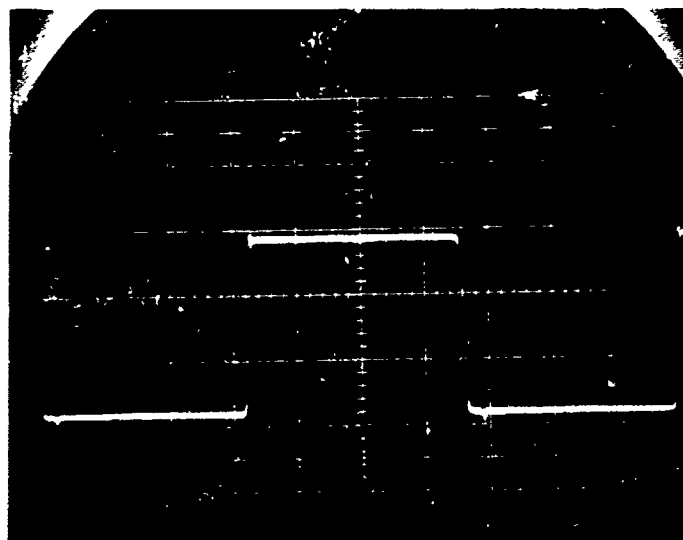
0.5 V/Maj. Div.

(Corresponds to
10 A/Maj. Div.)

0

Time - 10 μ S./Maj. Div.

Figure 21.
Total Current Sensing Voltage Signal (Terminals S/T of A4)



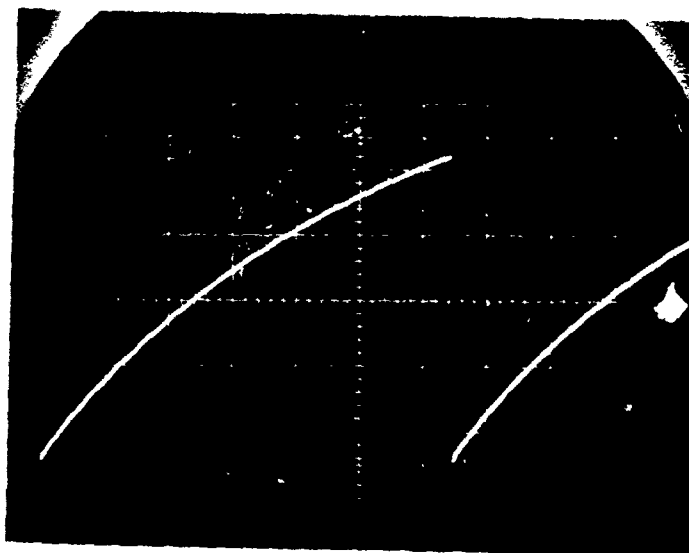
Output Two-State Voltage
of Hysteretic Threshold
Amplifier

5 V/Maj. Div.

0

Time - 10 μ S./Maj. Div.

Figure 22.
Output Two-State Voltage from Systeretic Threshold Amplifier
(Collector of A2Q3)

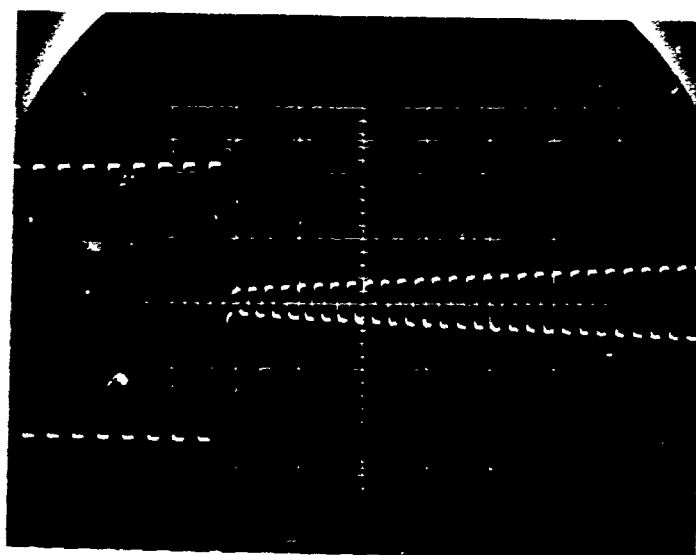


Sawtooth Modulating
Voltage

2 V/Maj. Div.

Time - 2 mS./Maj. Div.

Figure 23.
Output Voltage of Unijunction Sawtooth Oscillator
(Emitter of A2Q8)

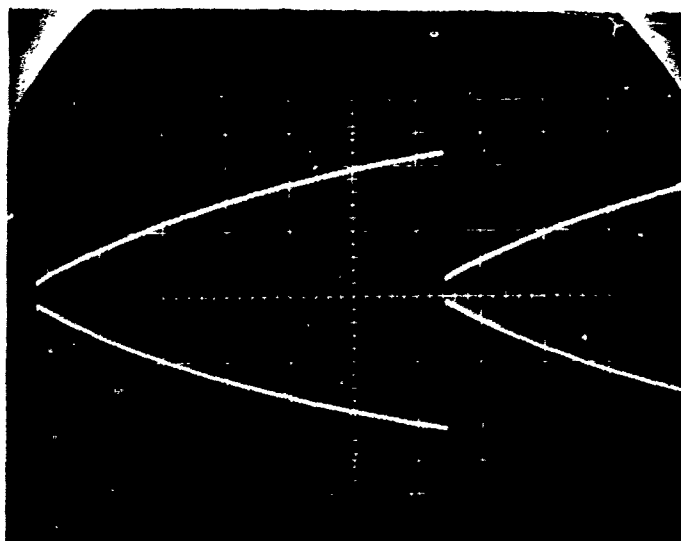


Modulated Two-State
Feedback Voltage

2 V/Maj. Div.

Time - 0.2 mS./Maj. Div.

Figure 24.
Modulated Two-State Feedback Voltage
(Terminal 6 of Amplifier A2U4)



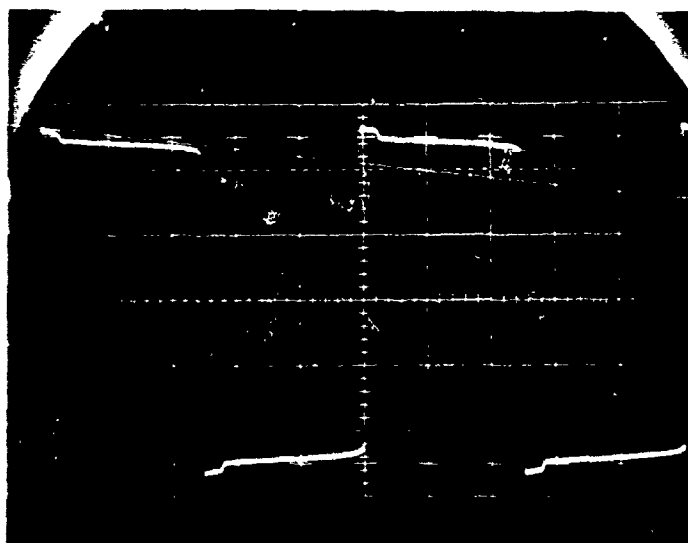
Modulated Two-State
Feedback Voltage

2 V/Maj. Div.

- 0

Time - 2 mS./Maj. Div.

Figure 2 5.
Envelope of Modulated Two-State Feedback Voltage
(Terminal 6 of Amplifier A2U4)



400 Hz Square Wave
Timer Motor Drive
Voltage

10 V/Maj. Div.

- 0

Time ~ 0.5 mS./Maj. Div.

Figure 26.
400 Hz Square Wave Drive Voltage for Timer Motor
(Terminals C/D to A/B of Assembly A3)

5. MECHANICAL CONSIDERATIONS

5.1 General Design

The mechanical design of the PP-4126()/U Battery Charger is described briefly in this section of the report. The mechanical design of the battery charger housing has three major objectives:

1. To provide ruggedness in order to withstand severe shock, vibration and bounce requirements.
2. To transfer heat generated within the battery charger to ambient air with a minimum housing temperature rise.
3. To protect the electronic circuits within the battery charger from water, sand and dust.

Photographs of the battery charger housing are shown in Figures 1 and 2. The sides and bottom of the unit are finned to provide better transfer of heat to ambient air. The top cover of the battery charger protects the front panel controls and serves as a housing for the input power cable. The cover is attached to the battery charger body with a strap. The body of the battery charger is composed of two cast sections termed the "upper housing" and the "lower housing." The two housing sections may be parted by loosening four screws. A drawing showing the battery charger in the open condition is included in Figure 27. When opened in this manner, the battery charger is fully operable. This permits testing and aligning the circuits within the battery charger without the use of an external test rack.

The upper and lower housing of the battery charger are constructed through the use of aluminum investment casting techniques. The basic housing casting has an excellent surface finish and good dimensional tolerances so that machining is required only to provide threads for screws. A disadvantage of the investment casting approach is that the castings tend to be quite rigid and brittle. Therefore, the castings must be made rather heavy in cross section in order to prevent fracturing during the drop and bounce tests. The thick sections of the castings greatly increase the weight of the battery charger relative to the weight of a case fabricated using brazed extruded parts. However, an advantage of the cast case is that its structural integrity is maintained throughout the bounce and drop test so that components and modules within the battery charger do not suffer significant mechanical deformations.

The layout of components and modules within the battery charger can be observed in Figure 27. Most of the power dissipated as heat within the battery charger emanates from the power handling module (A4). This module is mounted in the lower housing so that heat can be directly coupled to the finned section of the lower housing. An aluminum "L"

bracket on the power handling module transmits heat from the power handling components to the surface of the lower housing. The three-printed circuit Assemblies, A1, A2 and A3, are located at one end of the lower housing. These assemblies slip into metal guides which are mounted on the sides of the lower housing. A printed flexible wiring harness makes connection with connectors at the end of the printed circuit modules and at the top of the power handling module. The printed wiring harness assembly accomplishes nearly all of the wiring interconnections required within the battery charger. Only five high-current wire connections are made with discrete wiring. The printed wire harness approach is thought to greatly increase the reliability of the battery charger and also to reduce the cost of the wiring harness. EMI Assembly, A5, is located at the end of the lower housing opposite the printed circuit boards. This filter assembly provides initial filter action to confine large interference signals to the lower section of the battery charger. Additional EMI filtering is provided in Assembly A6, designated filter Assembly B and filter Assembly C in Figure 27. This assembly is located against the inside of the front panel of the upper housing. The other controls are also located on the upper housing as can be observed in Figure 27.

Additional information regarding component location within assemblies can be observed in Figures 28 through 36.

5.2 Mechanical Performance

The mechanical performance of the battery charger is in compliance with the technical requirements with the exception of weight. The weight of the battery charger, approximately 31.5 pounds, exceeds the specified 30 pound limit. The excessive weight can be attributed to two major causes: The investment castings, and the EMI filters. A conservative design approach necessitated thick cast wall sections in order to insure survival during the drop test. Future design optimization studies may enable a reduction in the wall thicknesses. In order to allow the battery charger to comply with the requirements of MIL-STD-461, extremely sophisticated EMI filtering using multiple section filters are employed within the battery charger. These filters account for approximately 30% of the internal volume of the battery charger. Thus a reduction in the size of these filters either through the use of smaller components or by re-examining the EMI specification could allow significant reduction in the weight.

Low Temperature Test

The low temperature test was repeated at BOSF Corporation. The timer which failed to operate properly at -50°F following a soak at -65°F was tested at -40°F. The unit operated successfully at -50°F following a -50°F soak.

A second timer was tested at -50°F following a -65°F soak. This timer of the same design, performed properly.

The use of a lubricant with minimal low temperature viscosity should permit all timers to operate properly under the specified low temperature limits.

Drop Test

The drop (shock) test was repeated utilizing the battery charger unit which had previously failed this test. The front casting was modified, incorporating corner flanges to capture the cover under severe shock conditions. This modification was necessary since the cover had broken loose during the previous drop test. However, the remaining components of the battery charger had been subjected to and had survived the previous drop test.

The repetition of the drop test showed that the casting modification was successful in retaining the cover. During this second drop test, an inductor broke loose on the power handling module. Subsequent vibration of the inductor ripped one cable run--preventing proper electrical operation following completion of the drop test sequence. Since the inductor did not break loose until it had experienced more than 26 drops including at least one drop in every orientation, the inductor mounting is adequate to comply with the normal shock test sequence.

Therefore, the two drop tests collectively show that a new battery charger should survive the drop test sequence.

A note of explanation is in order regarding the use of the same battery charger for both drop tests; only six battery chargers have been constructed to date. Since the drop test is potentially a damaging test, the same unit was used for both drop tests in order to minimize risk.

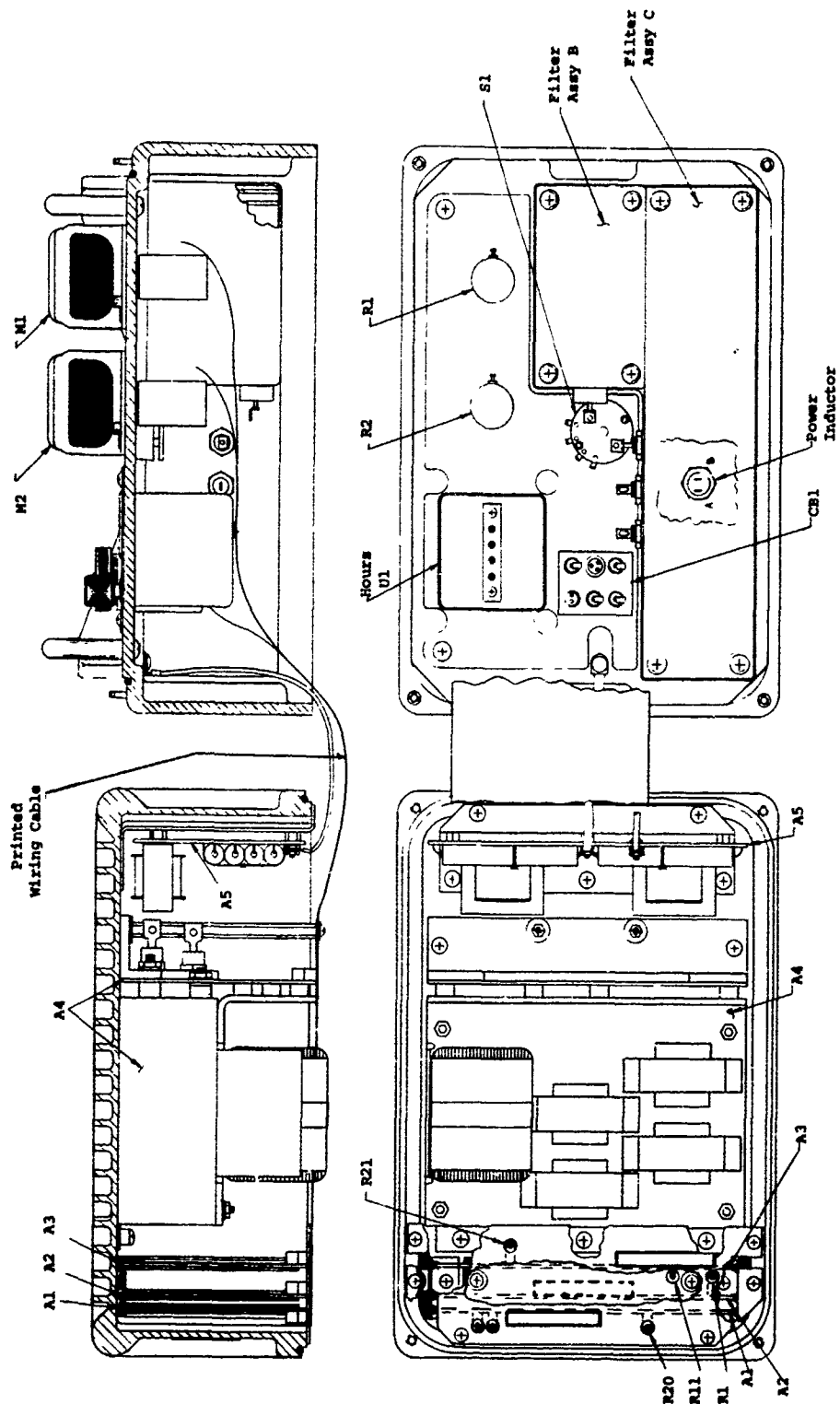


Figure 27 . Battery Charger PB-4126()/U
Interior Component Locations

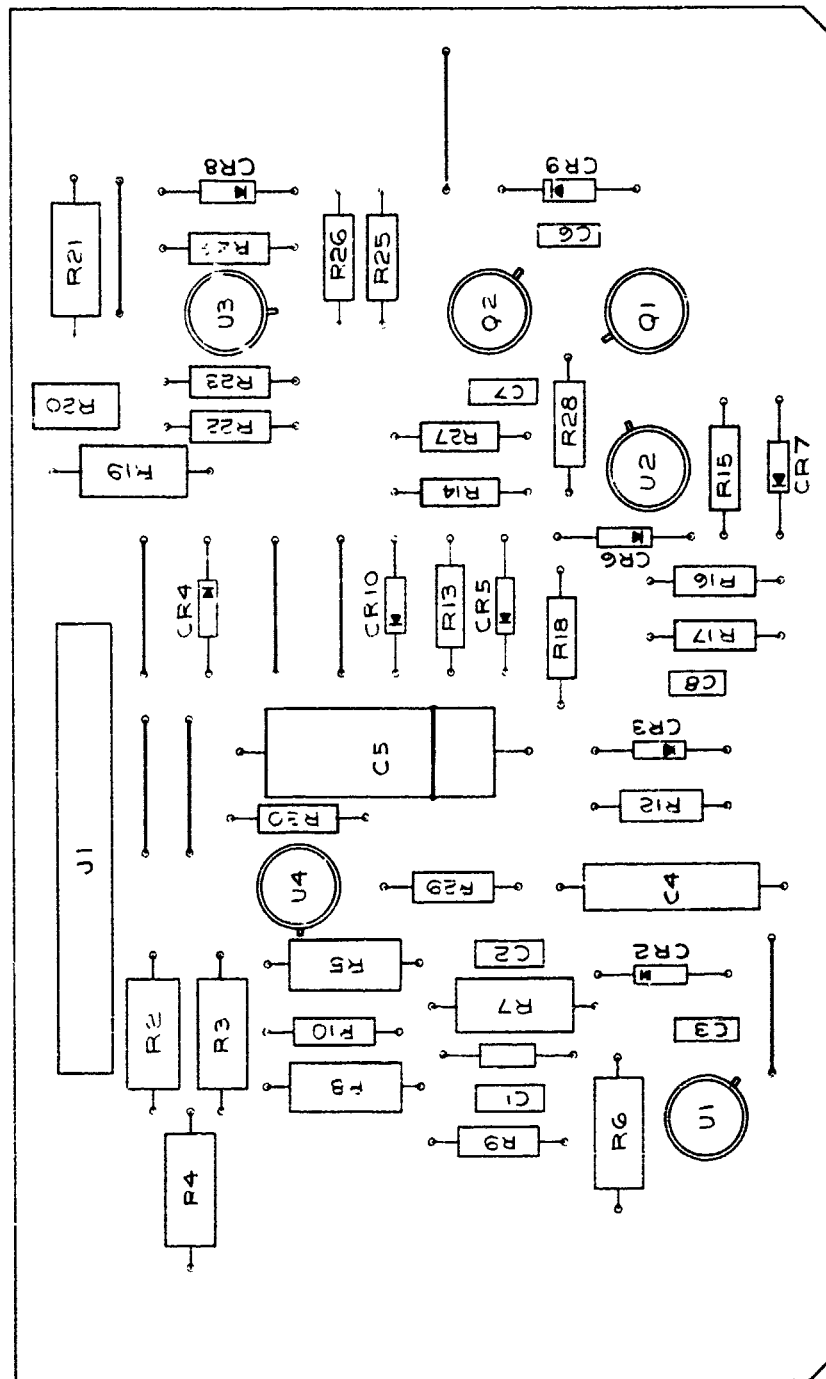


Figure 25. Volts Logic P.C. Board

(A1) Component Locations

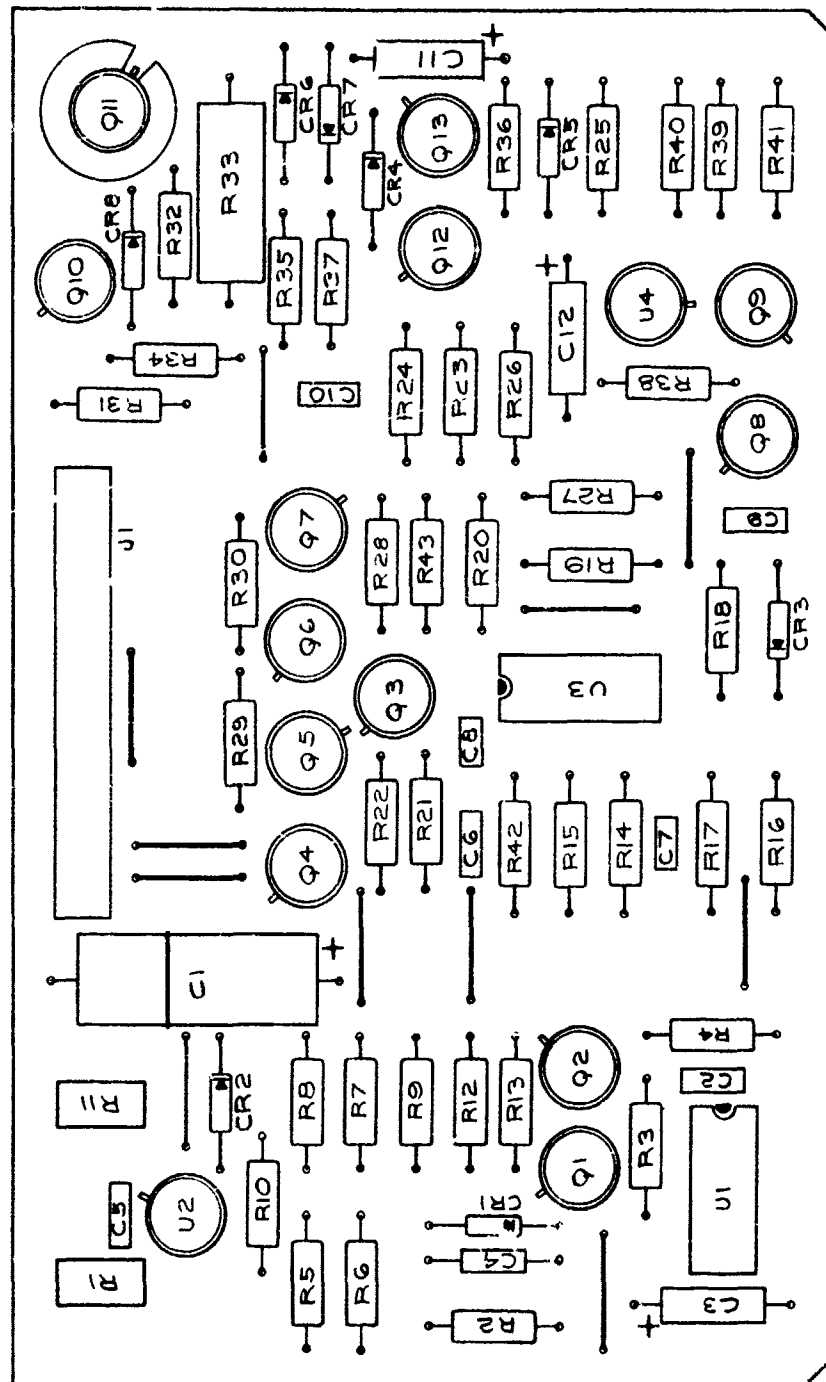


Figure 29. Amperes Logic P.C. Board
(A2) Component Locations

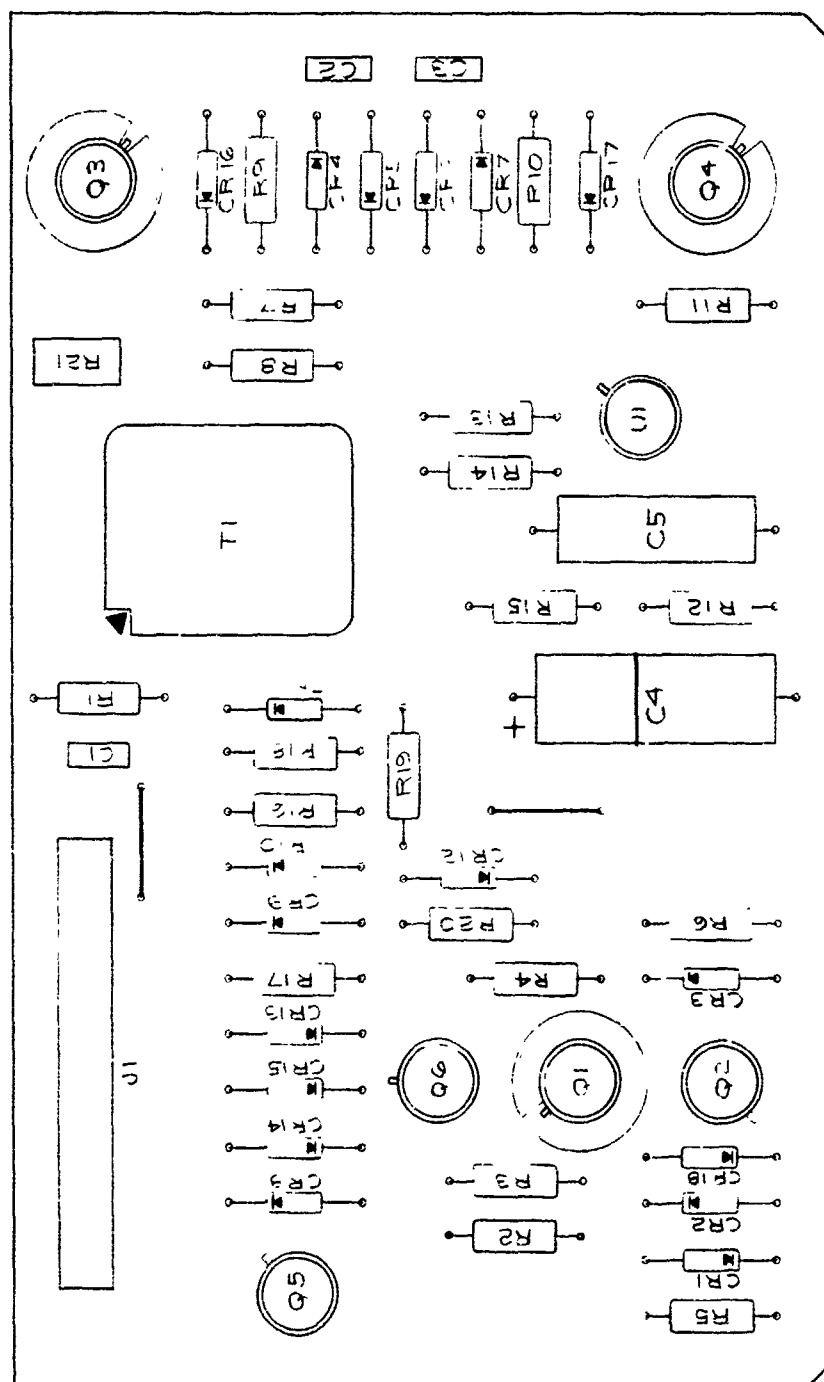


Figure 30. Hours Logic P.C. Board
(A3) Component Locations

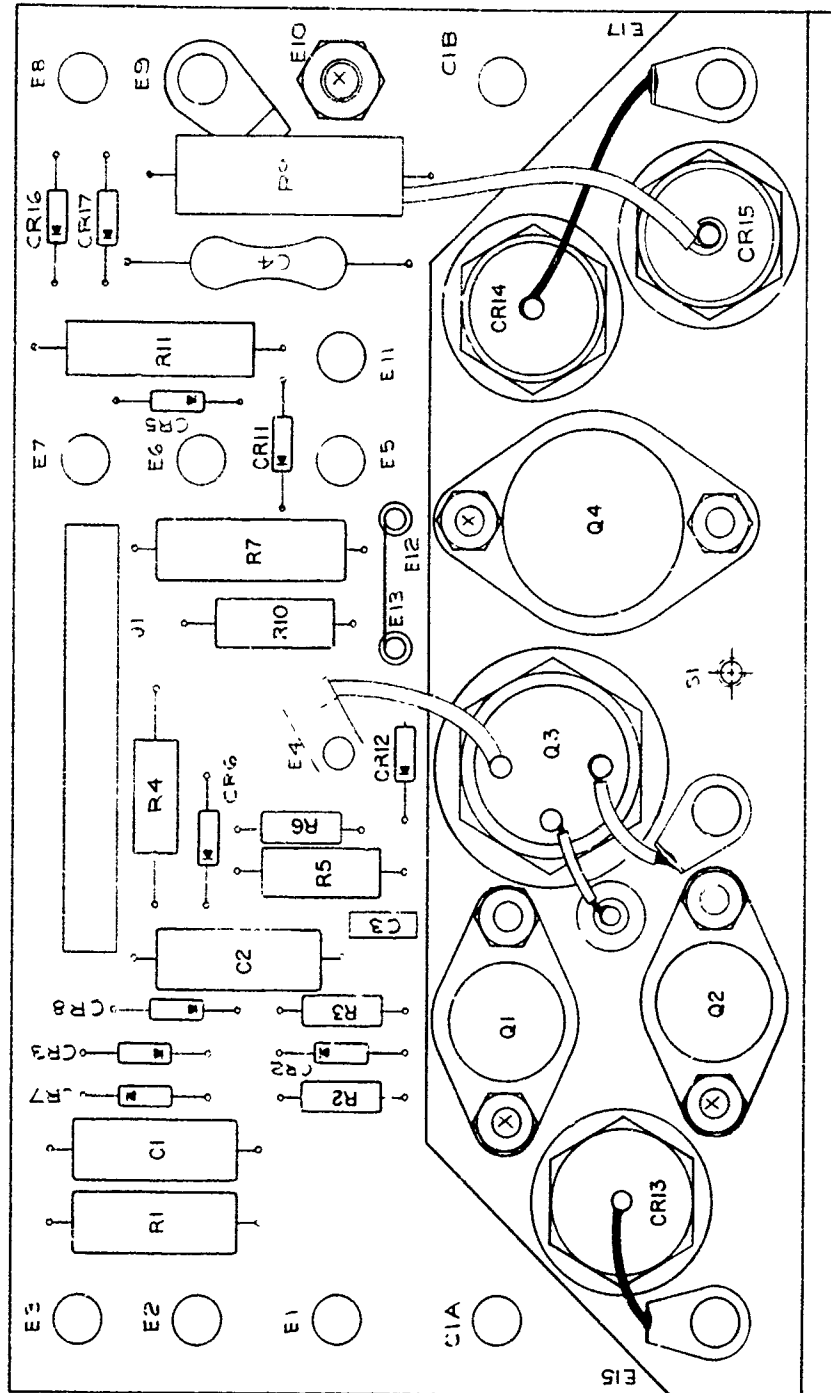


Figure 31. Power Handling Circuit (A4)

Component Locations (Sheet 1 of 2)

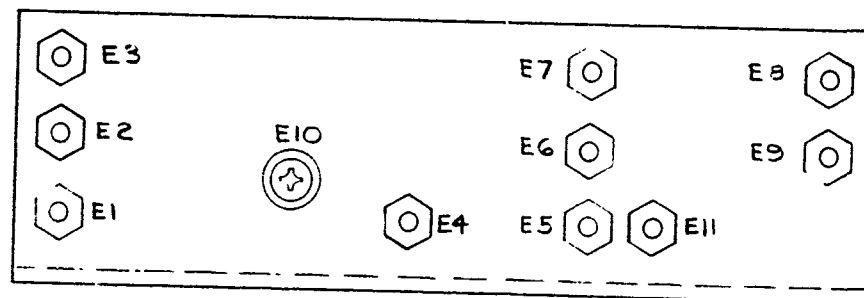
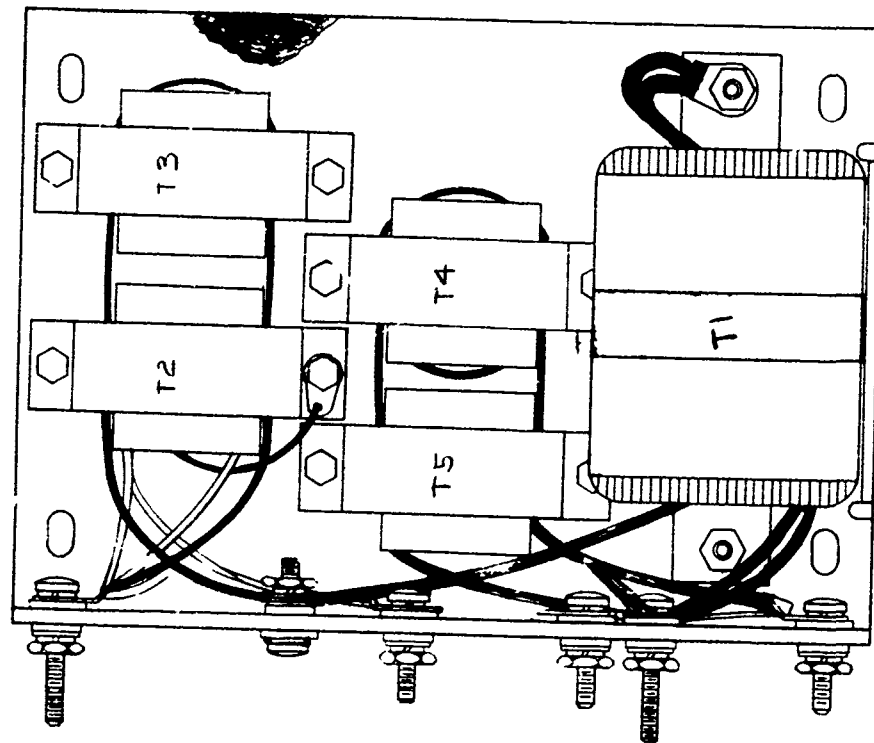


Figure 37. Power Handling Circuit (A4)
Component Location (Sheet 2 of 2)

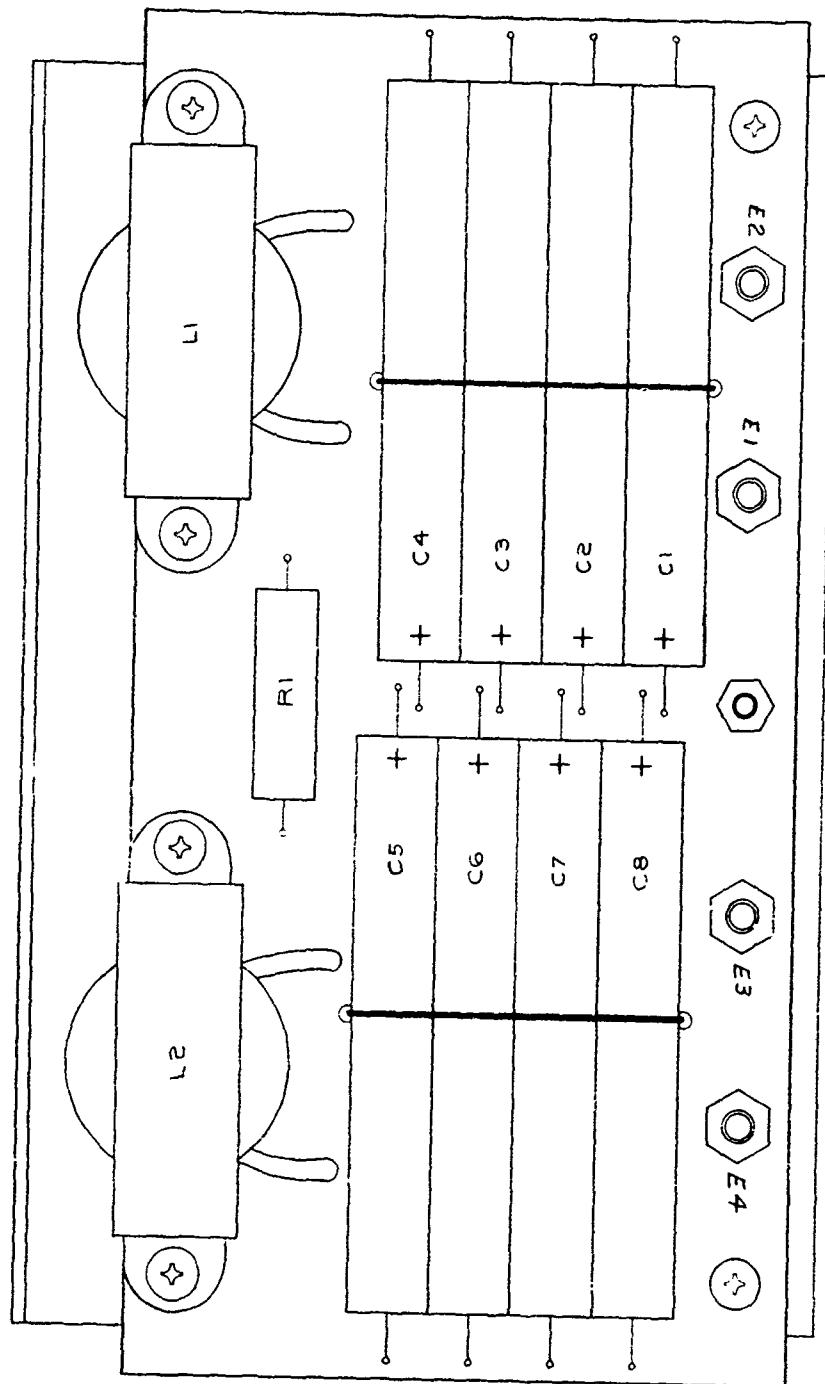


Figure 34. EMI Filter A Assembly
(A5) Component Locations

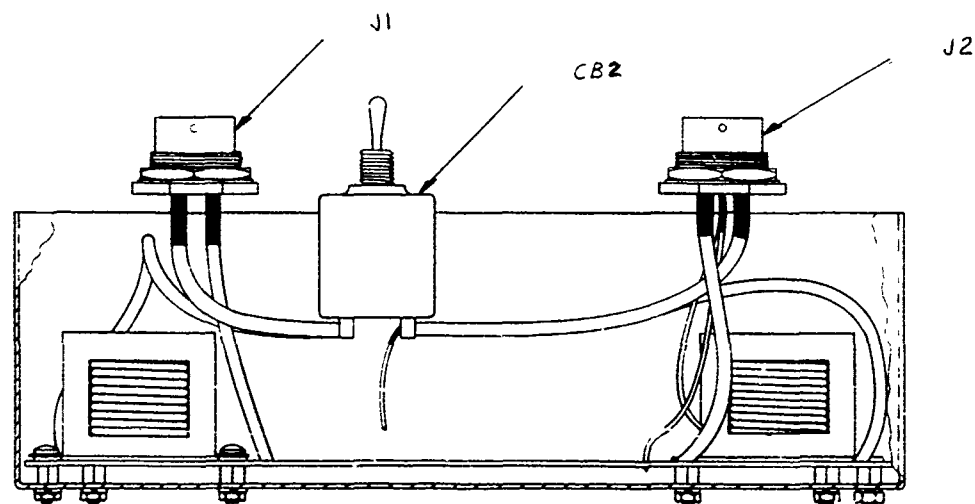
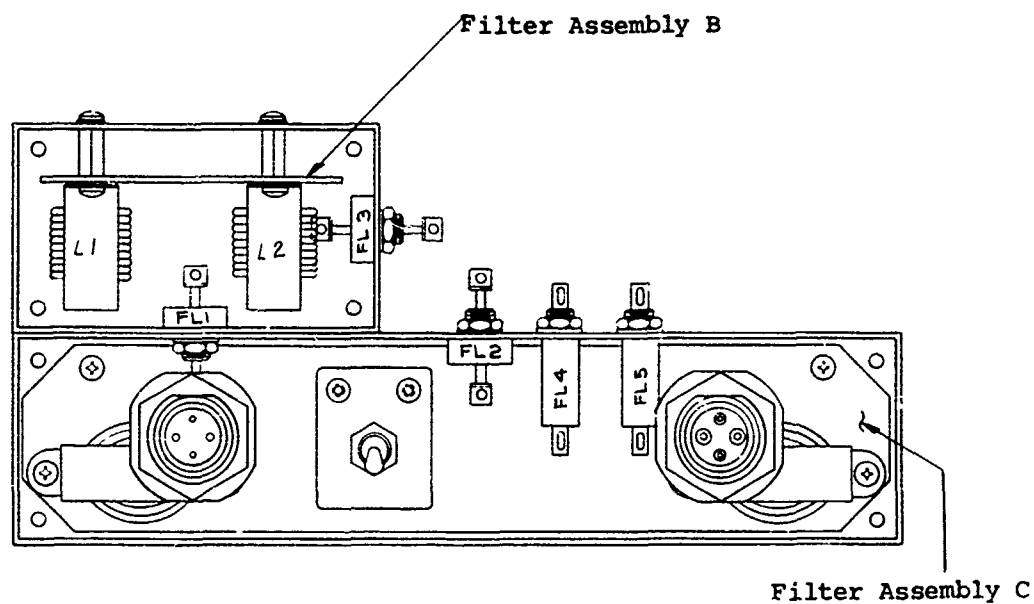


Figure 34. EMI Filter B/C Assembly
(A6) Component Locations

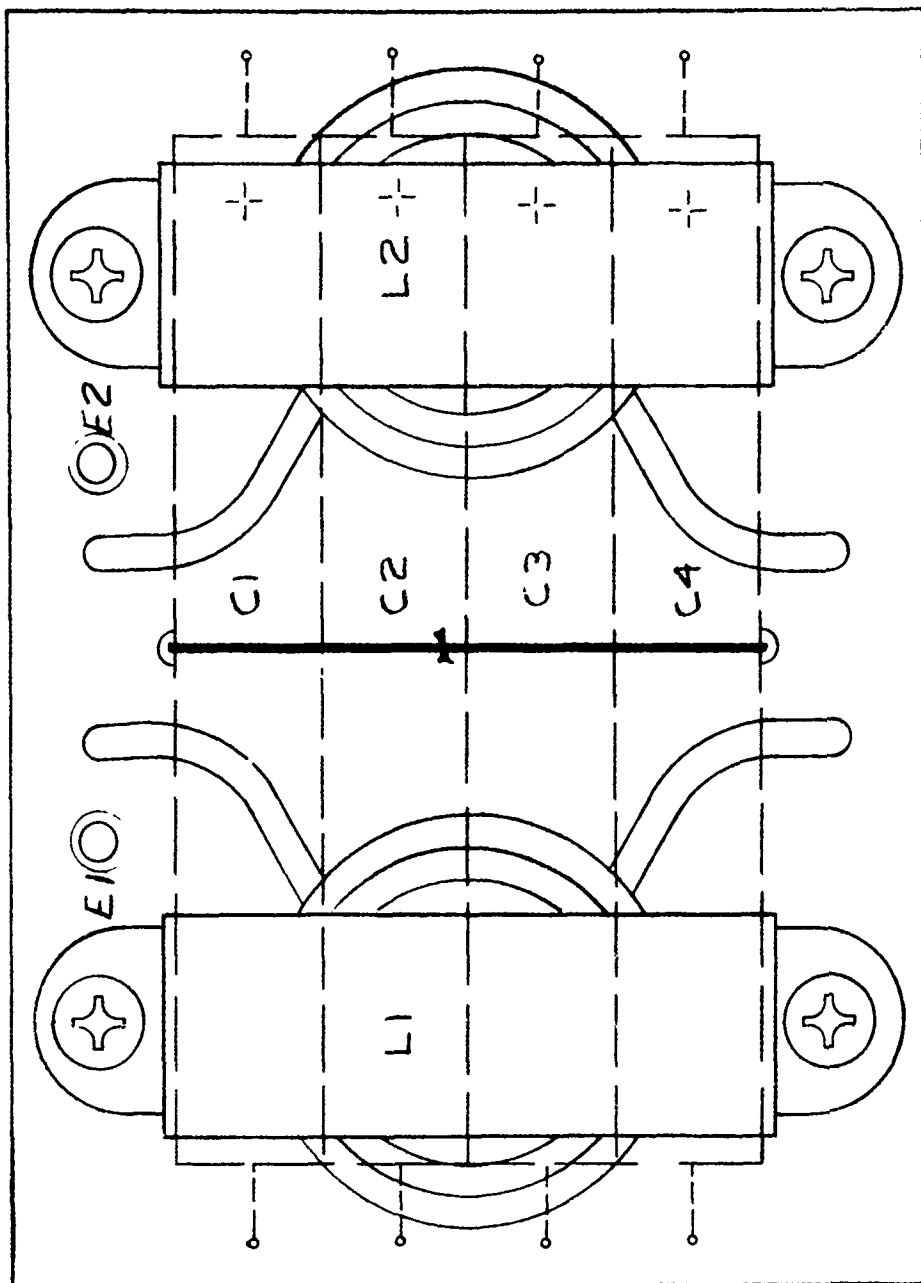


Figure 3 EMI Filter B Subassembly
(P/O A6) Component Locations

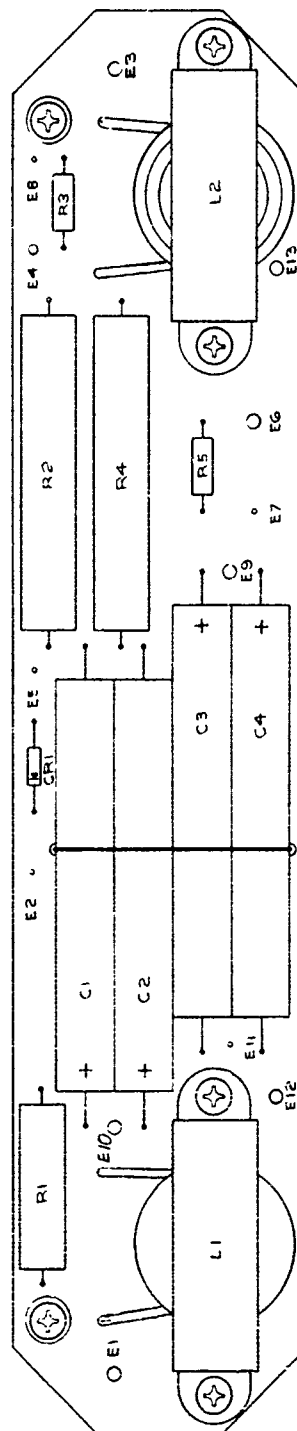


Figure 3. EMI Filter C Subassembly
(P/O A6) Component Locations

6. CONCLUSIONS AND RECOMMENDATIONS

The performance of the PP-4126()/U Battery Chargers complies with the requirements of the technical description with the exception of weight. Therefore, the performance of the battery charger is considered to be at a level commensurate with the actual field performance requirements. The problem of excessive weight can be alleviated through future design optimization.

APPENDIX A
CURRENT-CONTROLLED TWO-STATE
MODULATION SYSTEM

CURRENT-CONTROLLED TWO-STATE MODULATION SYSTEM

The following discussion presents some of the major characteristics of the current-controlled two-state modulation system in relation to those characteristics desirable in a modulation system in general.

The most salient factor that distinguishes current-controlled two-state modulation systems from others is that switching is initiated by feedback from the output of the power switches prior to filtering of the switching waveform. This factor is responsible for most of the system advantages that will be discussed in this section.

The task of evaluating the applicability of a modulation system to the field of power processing can be a deceptive one. Intuition and tradition tempt one to make the evaluation on the basis of performance specifications of a power processing unit incorporating the modulation system. Such an approach would attempt to evaluate the modulation system in terms of regulation, transient response, available ranges of output variables and other parameters commonly used to describe power processing systems. However, further reflection reveals that by the addition of suitable circuitry, with its associated complexity, a wide range of modulation systems can be tailored to meet a given set of specifications. In fact, the attainable specifications of a power processing unit are often dictated more by the ingenious circuits employed to compensate for inherent deficiencies in the modulation system than by modulation systems themselves. For example, relatively complex circuitry is often required to attempt dissipationless output current limiting, instantaneous control of switching device current under line and load variations, and rapid line transient response in modulation systems for which such characteristics are not inherent. The additional circuitry required to compensate for deficiencies in the modulation system not only adds complexity but entertains the possibility of nonlinear modes which can cause system failure.

An appropriate measure for modulation systems is one which examines the degree to which the desirable features in power processing applications are inherent in the particular system. A good modulation system, therefore, is one that is simple and inherently incorporates as many of the features desired in power processing applications as is possible. The current-controlled two-state modulation system (Figure A1) was specifically designed to meet this criterion and appears to be a versatile system that inherently encompasses some important features for

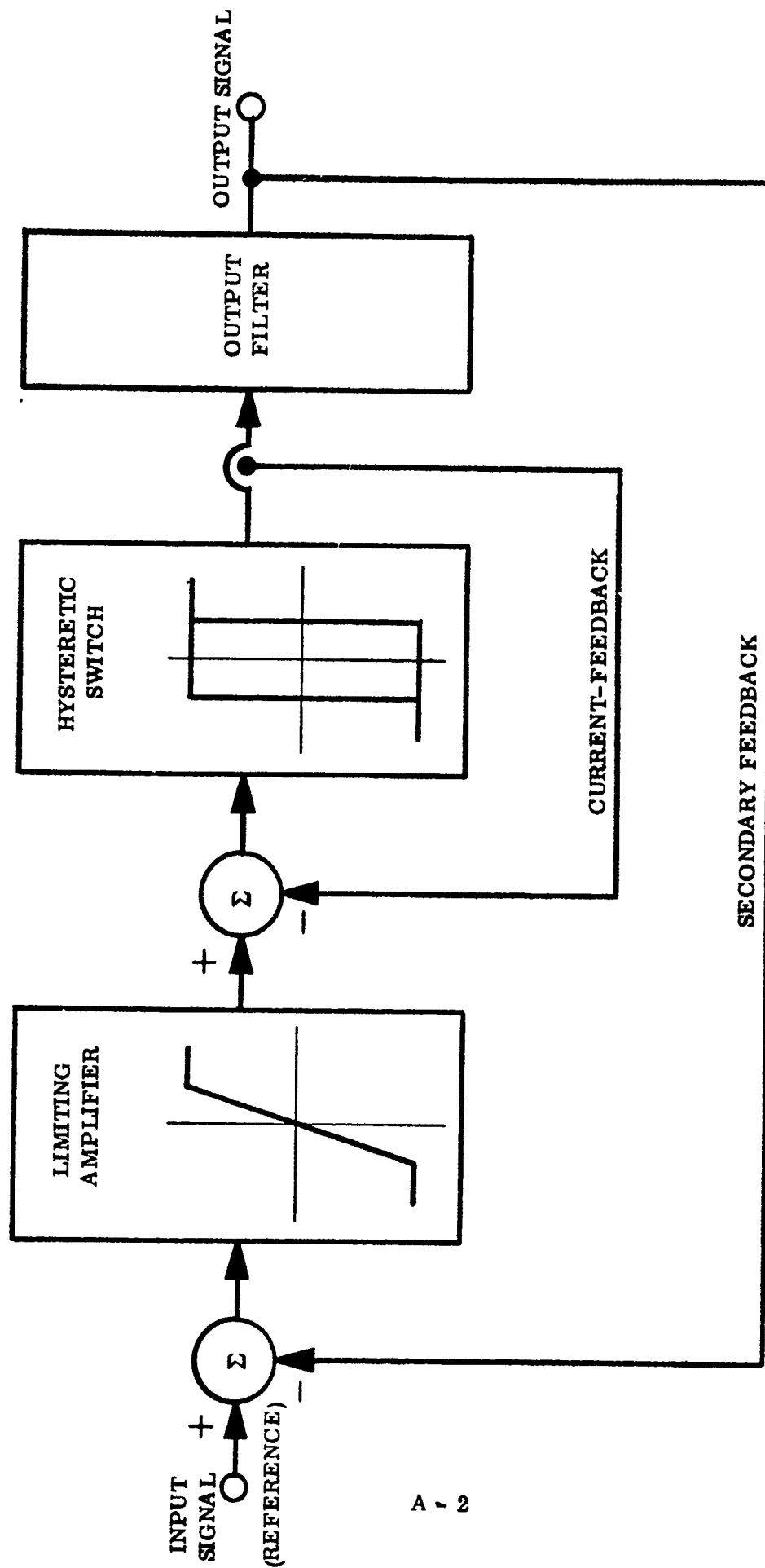


Figure A.1

CURRENT-CONTROLLED TWO-STATE MODULATION SYSTEM

power processing applications, as summarized below:

1) Inherent Control of Currents in Power Switches

As a consequence of the fact that the current in the power switch is directly fed back to initiate switching, this current is controlled to the desired level under all transient and steady state conditions of line and load.

2) Inherent Current Limiting

Current limiting is a consequence of the action of the limiting amplifier as indicated in Figure A1. The maximum output current is directly proportional to the amplitude of the limiting level and is controllable if desired.

3) Inherent High Degree of Line and Load Regulation with Stability and Wide Bandwidth

Variations caused by the input line are suppressed by both the high-gain current and secondary feedback loops that are inherent in the modulation system. Variations caused by load are suppressed by the gain of the secondary feedback loop from the output that is inherent in the modulation system. The gain of the secondary feedback loop can be high compared to that of many other systems because the stability problems usually introduced by the output filter are removed (by the current feedback loop) as far as the secondary feedback loop is concerned. The gain of the secondary feedback loop can easily be made sufficiently high, with unconditionally stable operation, such that the reference source is the only limitation for static regulation. Since neither feedback loop (with both loops active) experiences more than 90° phase shift due to the output circuits, wide bandwidth of the secondary feedback loop is easily achieved with stability. Thus, fast response times are inherent in the current-controlled two-state modulation system.

4) Inherent Capability for Paralleling with Proportional Current Sharing

The inner current feedback loop of the current-controlled two-state modulation system (Figure A1) forms a well controlled current amplifier. Therefore, power processing units employing this system can be paralleled with current sharing simply by connecting a single

limiting amplifier to drive all the inputs of the paralleled controlled current amplifiers.

5) Wide Range Of Applicability with Respect to Output Circuits

The current-controlled two-state modulation system lends itself easily to many different power handling circuit configurations including direct (chopper) and inverted (flyback) circuits. This is an advantage for a modulation system since it then encompasses a wide variety of circuit realizations which include different trade-offs between parameters (i. e., the required magnitude of switch currents and the size of energy storage elements) for a given set of specifications on a power processing unit.

The discussion above, while serving to illustrate the features and versatility of the current-controlled two-state modulation system is by no means intended to portray it as the optimum solution to all power processing problems. Operational constraints and properties of switching elements may dictate trade-offs favorable to other approaches in particular circumstances. If, for example, selected frequencies are restricted for reasons of controlling radio frequency interference (RFI) it may sometimes be advantageous to use pulse-width modulation. Extremely stringent RFI constraints may, on occasion, rule out all modulation systems in favor of linear systems. Switching devices without turn-off capability may sometimes be better handled by resonant turn-off approaches and consequent pulse frequency modulation control.

CURRENT-CONTROLLED TWO-STATE MODULATION USING SINGLE CURRENT FEEDBACK LOOP

A diagram of the simplest form of the current-controlled two-state modulation system is shown in Figure A2. This basic system utilizes a single current feedback loop to provide a controlled average current flow through the output inductor such that

$$\overline{i_L} = \frac{v_d}{R_c} \quad (A1)$$

where $\overline{i_L}$ = average value of i_L . Thus, this basic system is useful in many

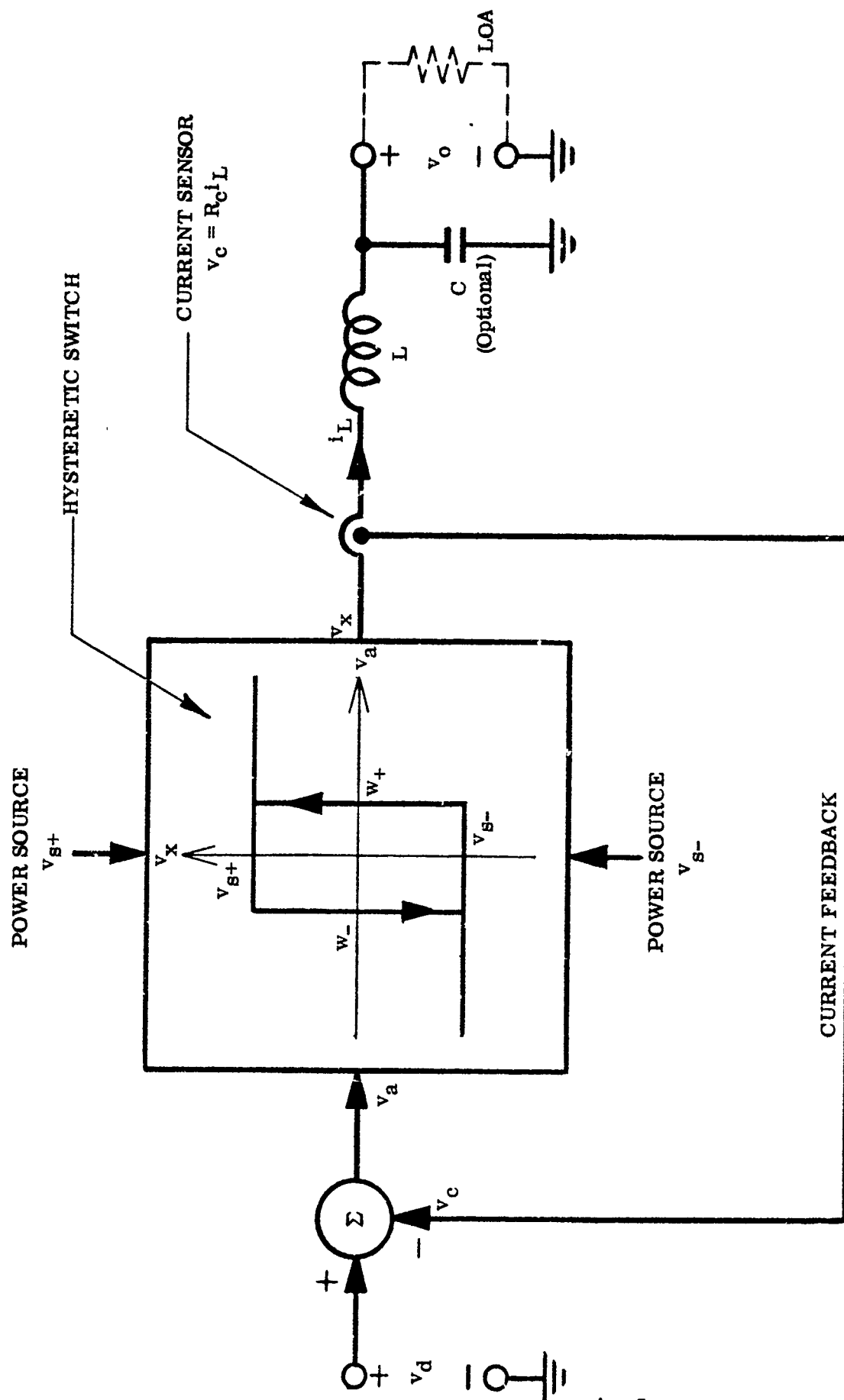


Figure A.2

CURRENT-CONTROLLED TWO-STATE MODULATION SYSTEM
(SINGLE FEEDBACK LOOP)

applications where output current regulation or control is desired. Typical examples are constant current battery charging and current fed sonar transducers.

The system of Figure A2 is self-oscillating: The output of the hysteretic switch shifts between voltage states v_{s+} and v_{s-} . These shifts in output voltage state are controlled by an actuating signal v_a . In practice, voltage v_a can be considered to be an error signal which is constrained to lie within the input voltage thresholds of the hysteretic switch. That is:

$$w_- \leq v_a \leq w_+ \quad (A2)$$

Since the actuating voltage is derived by comparing the current feedback signal v_c to the input drive signal v_d , the bounds on voltage v_a imply that the difference between voltages v_d and v_c is also bounded. Thus, it is possible to write the expression:

$$\frac{w_-}{R_c} \leq \frac{v_d}{R_c} - i_L \leq \frac{w_+}{R_c} \quad (A3)$$

It is important to note that Equation A3 is valid if and only if $v_{s+} < v_o < v_{s-}$. Normally, the hysteretic switch must oscillate between states at a rapid rate in order to maintain the output current level i_L within the bounds indicated in Equation A3. Consider, for example, the case of a short circuit load. When the output state of the hysteretic switch is positive, v_{s+} , then the voltage impressed across inductor L is positive causing the current flow through the inductor to increase linearly with time. This results in a linear decrease in the actuating voltage, v_a , with time; however, when the actuating voltage reaches the negative input voltage threshold of the hysteretic switch, w_- , the state of the hysteretic switch shifts such that the output voltage becomes equal to v_{s-} . As a result, the voltage impressed across the inductor becomes negative and the current flow through the inductor decreases linearly with time. The current decrease continues until the actuating signal reaches the upper input threshold of the hysteretic switch, w_+ . At this point the output state of the hysteretic switch returns to the positive voltage state v_{s+} . Thus, the output of the hysteretic switch alternates between the positive state v_{s+} and the negative v_{s-} . This type of two-state oscillation is common to all forms of current-controlled two-state modulation systems.

It is important to emphasize the relationship between the input drive voltage v_d and the current flow through the inductor i_L . This relationship can be observed in Equation A3. That is the inductor current never differs from the drive level by more than the threshold voltage of the hysteretic switch divided by the gain of the current sensor R_c . If the thresholds of the hysteretic switch are made very narrow, this implies that the current flow through the inductor will nearly be equal to the input drive level. However, as the thresholds of the hysteretic are reduced, the switching rate of the hysteretic switch increases. It is not possible using the system of Figure A2 to obtain arbitrary accuracies through a reduction in the threshold levels because the switching frequency must remain finite in any practical realization of the current-controlled system. Thus, the ultimate realization of a current-controlled system represents a compromise between switching frequency and accuracy.

One important characteristic of current-controlled two-state modulation is that the output inductor, L , does not affect either the transfer function or the output impedance of the system. A linearized model of the current-controlled two-state modulation system of Figure A2 is shown in Figure A3. The inductor is eliminated from this linearized model because it appears in series with the current source created through the use of current feedback. Because the inductor is eliminated, the output circuit can have no more than 90° phase shift for any passive load. This permits the use of secondary feedback loops to implement additional control functions without incurring stability problems due to the LC output filter. The importance of the linear model shown in Figure A3 is more evident in the system shown in Figure A4 where an additional voltage feedback loop is implemented. Such a feedback loop cannot be implemented with other than marginal stability unless the loop phase shift due to the inductor is eliminated.

CURRENT-CONTROLLED TWO-STATE MODULATION SYSTEM UTILIZING TWO FEEDBACK LOOPS

A block diagram of the current-controlled two-state modulation system with an additional voltage feedback loop to implement output voltage control is shown in Figure A4. The output impedance can be reduced to a low value using voltage feedback causing the output to appear to be a voltage source. The output voltage source characteristic can be provided with wide bandwidth because no high frequency attenuating networks are necessary to stabilize the system. However, a high frequency ripple attenuating feedback network is utilized to reduce the gain at frequencies where output ripple would be excessive value

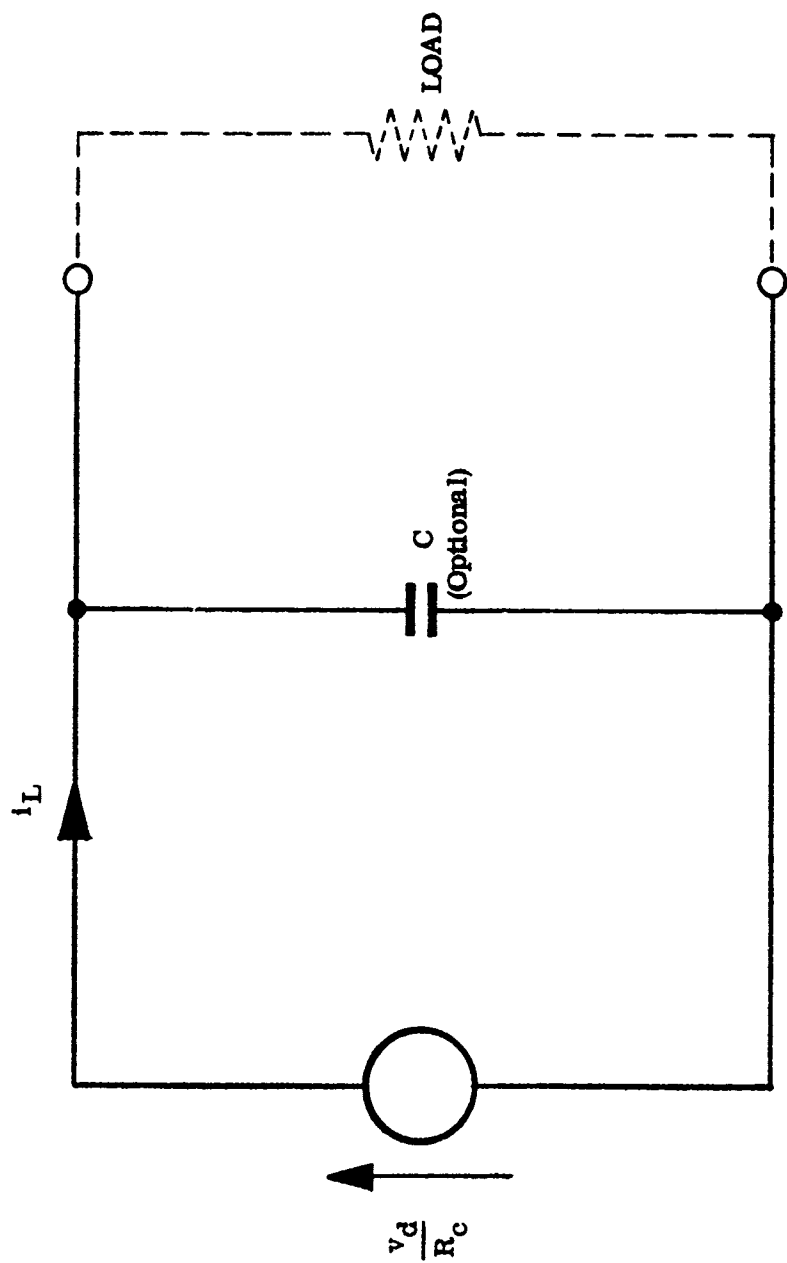


Figure A. 3

LINEAR MODEL OF CURRENT-CONTROLLED TWO-STATE MODULATION SYSTEM
(SINGLE FEEDBACK LOOP)

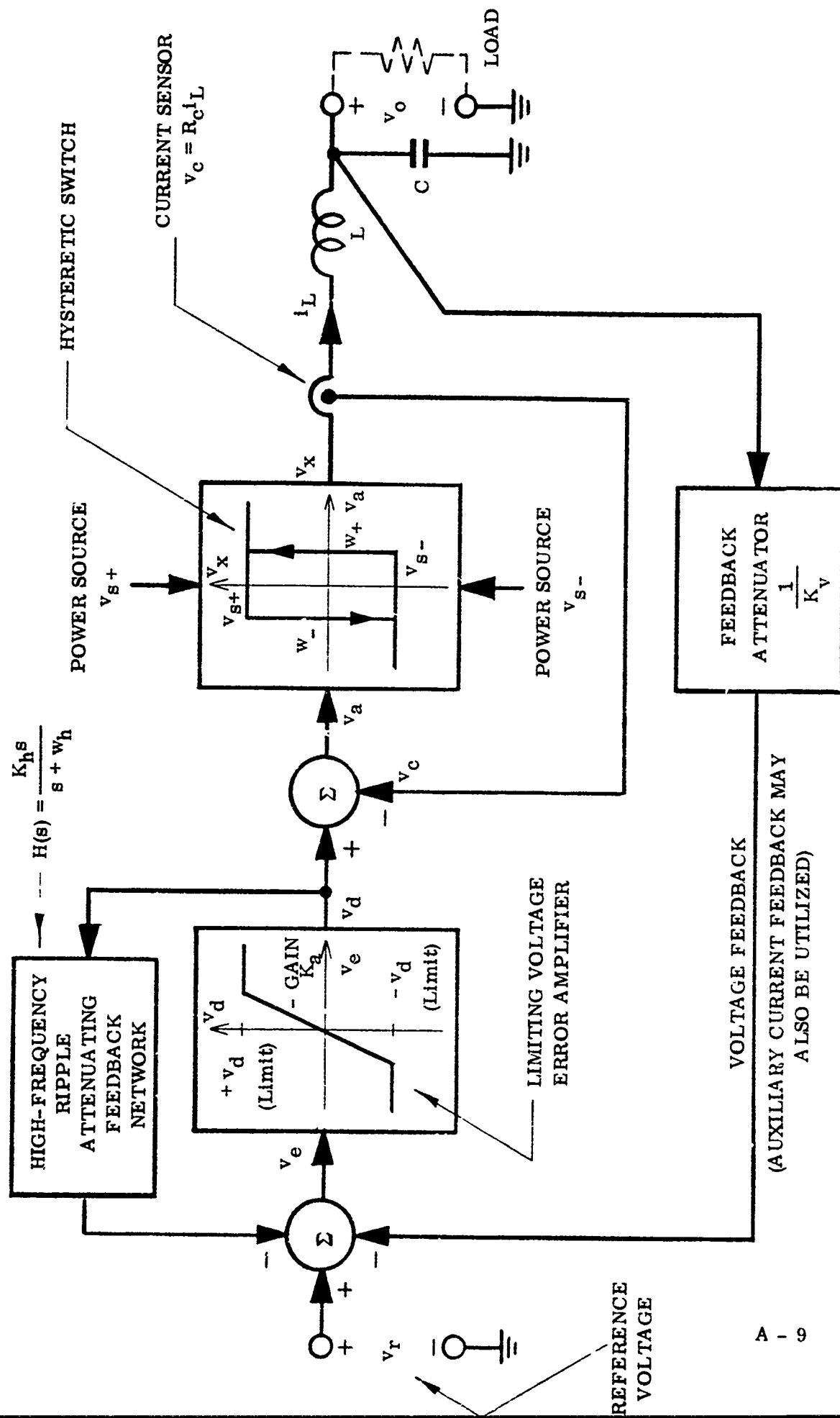


Figure A. 4

CURRENT-CONTROLLED TWO-STATE MODULATION SYSTEM
(VOLTAGE AND CURRENT FEEDBACK LOOPS)

due to the gain in the limiting voltage error amplifier. The ripple attenuating network is not necessary in order to obtain system stability; it is only used to prevent overloading of the limiting voltage error amplifier by the voltage ripple.

Inherent current limiting under all conditions of line and load is derived through the simple mechanism of limiting the maximum output of the limiting voltage error amplifier. Since the internal current feedback loop causes the output current, i_L , to be directly proportional to the output of the limiting voltage error amplifier, v_d , the limits on voltage v_d define limits on the output current. These current limits apply under all static and dynamic conditions. Therefore, the maximum peak current magnitude which can be obtained from the output of the hysteretic switch is

$$\begin{aligned} |i_L|_{(\max)} &= \frac{v_d(\text{limit}) + w_+}{R_c} & |w_+| &\geq |w_-| \\ |i_L|_{(\max)} &= \frac{v_d(\text{limit}) - w_-}{R_c} & |w_-| &\geq |w_+| \end{aligned} \quad (\text{A4})$$

When the current-controlled two-state modulation system of Figure A4 is not in the current limiting mode, its behavior with respect to output impedance and stability can be accurately predicted using the linear model shown in Figure A5. The output voltage can be derived from Figure A5; the expression for the output voltage is

$$v_o = \frac{K_v v_r \left[\frac{K_a(s + \omega_h)}{(1 + K_a K_h)s + \omega_h} \right]}{\frac{K_v R_c (R_L C s + 1)}{R_L} + \frac{K_a(s + \omega_h)}{(1 + K_a K_h)s + \omega_h}} \quad (\text{A5})$$

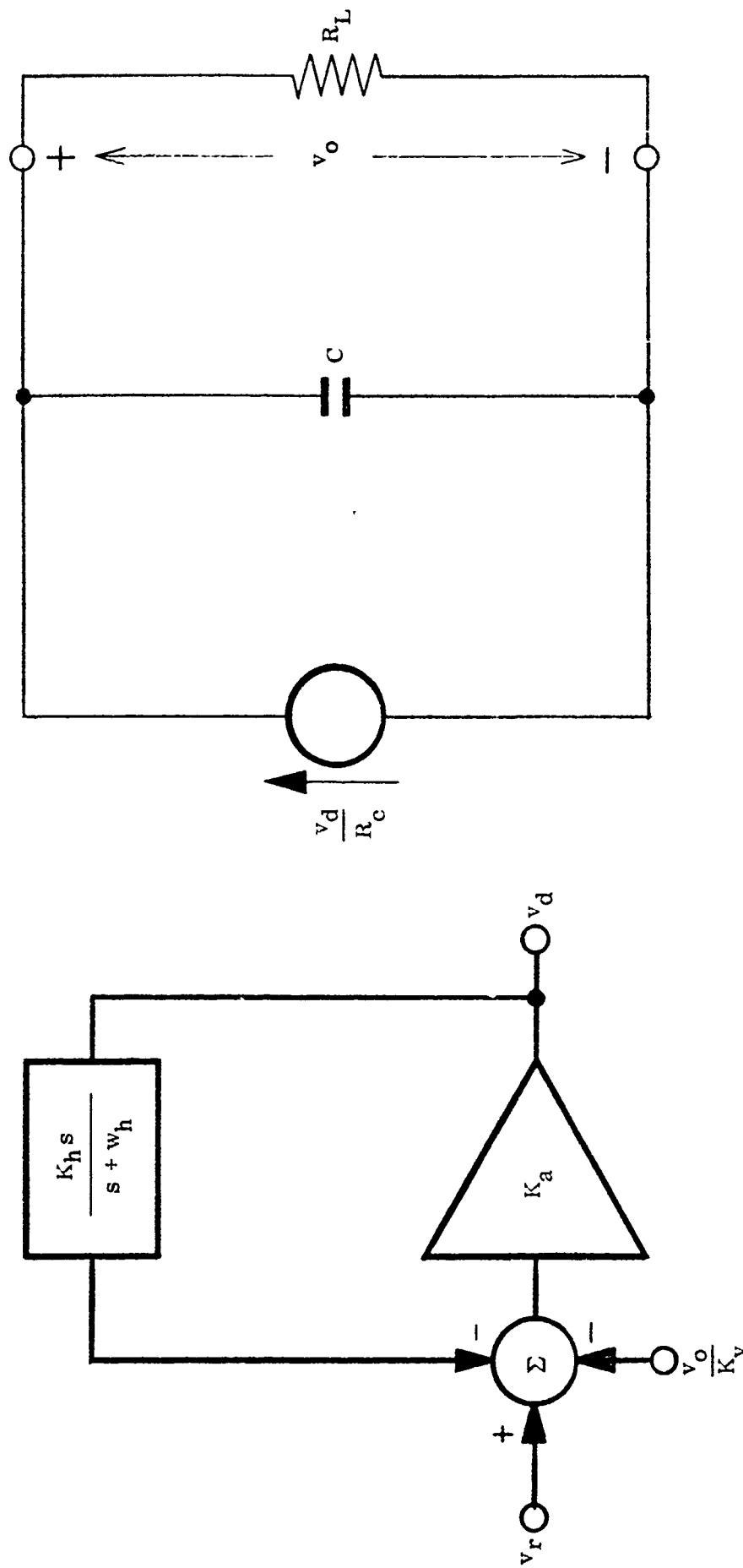


Figure A.5

LINEAR MODEL OF CURRENT-CONTROLLED TWO-STATE MODULATION SYSTEM
(VOLTAGE AND CURRENT FEEDBACK LOOPS)

The corresponding admittance can be expressed as

$$Y_O(s) = \frac{K_a(s + \omega_h)}{R_c K_v [(1 + K_a K_h)s + \omega_h]} - Cs \quad (A6)$$

$$\text{where } Z_O(s) = \frac{1}{Y_O(s)}$$

Normally gain factor K_a is very large and the product $K_a \cdot K_h$ is small. Inserting these conditions in Equations A5 and A6 results in Equations A7 and A8:

$$K_a \longrightarrow \infty$$

$$K_a K_h \longrightarrow 0$$

$$v_o \approx K_v v_r \quad (A7)$$

$$Z_O(s) \approx \frac{R_c K_v}{K_a} \longrightarrow 0. \quad (A8)$$

These equations apply when the gain conditions mentioned above are approximately valid. In such a case, the equations indicate that the output of the two loop current-controlled two-state modulation system appears to be a voltage source which is directly proportional to the reference voltage.

Another interesting condition is that of zero frequency or dc operation. In this case the relationship between the output voltage and the reference voltage can be expressed as shown in Equation A9.

$$v_o = \frac{K_v v_r}{1 + \frac{K_v R_c}{K_a R_L}} \quad (A9)$$

This equation reduces to the same result as Equation A7 when the condition of Equation A10 is satisfied.

$$K_a \gg \frac{K_v R_c}{R_L} \quad (A10)$$

For dc operation the output impedance can be expressed as shown in Equation A11.

$$Z_o(0) = \frac{R_c K_v}{K_a} \quad (A11)$$

Although the system of Figure A4 creates an apparent voltage source at the output terminals, it is important to recall that current is internally under instantaneous control at all times due to the internal current feedback loop. The use of current feedback provides continuous protection for the hysteretic switch preventing overcurrents and current spiking under any conditions of line and load. Additionally, the use of current feedback eliminates the effect of the inductor shown in Figure A4 permitting the use of the high gain voltage feedback loop without introducing instability. The internal current feedback loop also permits modular operation. Several hysteretic switches in conjunction with individual current feedback loops and individual inductors may be operated in parallel. These paralleled current amplifiers would be supplied with the output signal from a single limiting voltage error amplifier, v_d , resulting in identical output currents from the hysteretic switches through their individual inductors. The inductors are all connected to the output capacitor C. In this manner, modular operation of any number of hysteretic switches is possible.

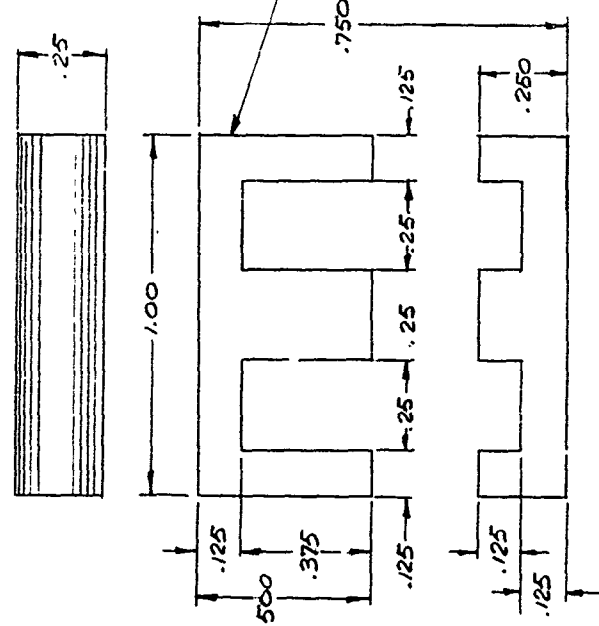
APPENDIX B

MAGNETIC ELEMENTS

				REVISIONS															
				LTR	DESCRIPTION											DATE	APVD		
REV STATUS OF SHEETS		REV SHEET	-	-															
		1	2																
DRAFTSMAN NAPOLITANO A.		DATE	CONTRACT NO. DAAB07-72-C-0219				BOSE CORPORATION NATICK, MASS. 01760												
CHECKER																			
ENG.			TITLE PARTS LIST TRANSFORMER, HOURS																
APPROVAL		CODE IDENT. NO. 32108		SIZE A	DRAWING NO. PL100823											LTR -			
APPROVAL		SCALE		UNIT WT.											SHEET 1 OF 1				

CORE (2)

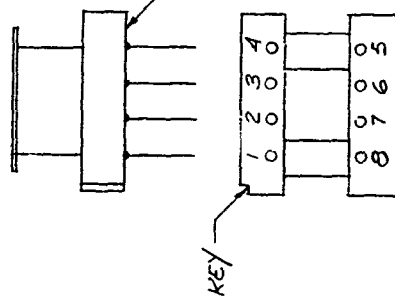
.014 THK LAMINATIONS
EE-24-25 PATTERN
MATERIAL: 50% NICKEL 50% IRON
(BY WEIGHT)



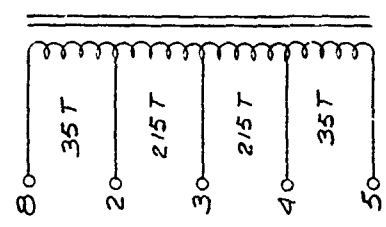
SQUARE STACK, FULL INTERWEAVE

FIRST WINDING:
TWO BIFILAR WINDINGS, 215 \pm 10 TURNS
OF (1)

SECOND WINDING:
TWO BIFILAR WINDINGS, 35 \pm 4 TURNS
OF (1)



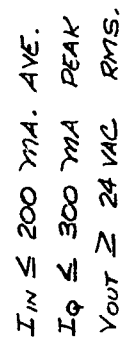
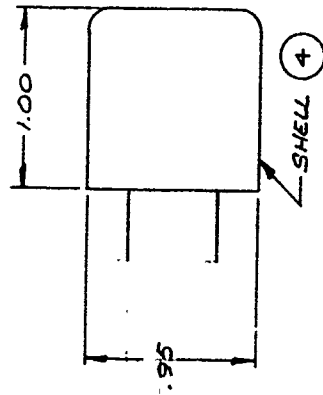
WINDING



SCHEMATIC

REVISIONS		
REV.	DESCRIPTION	DATE
-	NEW ISSUE	
A	215 WAS 115	9/11/72 RW

REV. STATUS OF SHEET	REV. A	QTY. REQD. -2	QTY. REC'D. -1	PART OR IDENTIFYING NO.	DESCRIPTION	REF. DES. OR REMARKS	ITEM NO.
LIST OF MATERIAL							
CRAFTSMAN				DATE			
M. S. /				6/25/72			
CHECKER				4/29/72			
INSP.				1/15/73			
COSTS				02-72-5-0219			
APPROVAL				APPROVAL			
100821				4/26			
NEXT ASSY				UNDO ON			
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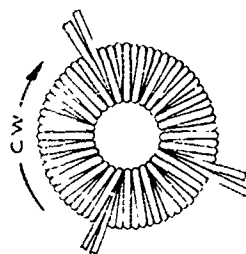
TEST

[illegible]

				REVISIONS																																			
				LTR	DESCRIPTION											DATE	APV																						
REV STATUS OF SHEETS		REV SHEET	-	-																																			
DRAFTSMAN NAPOLITANO A		DATE 1/19/73	CONTRACT NO. DAAB07-72-C-0219											BOSE CORPORATION NATICK, MASS. 01760																									
CHECKER			TITLE PARTS LIST INDUCTOR EMI FILTER																																				
ENG.																																							
APPROVAL			CODE IDENT. NO. 32108			SIZE A			DRAWING NO. 100843										LTR -																				
APPROVAL			SCALE			UNIT WT.										SHEET 1 OF 2																							

A diagram showing a 3x3 grid of cells. The top-left cell is pointed to by a line from a circled '1'. The bottom-right cell is labeled 'TIO REF'.

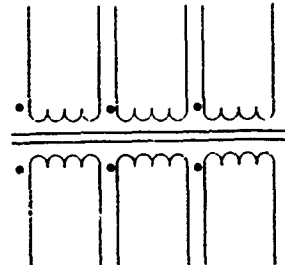
Technical drawing of a cable cross-section. The central core consists of 12 strands. The diameter of the central core is labeled as $2 \frac{1}{8}$ MAX. The jacket thickness is labeled as $2 \frac{1}{2}$ MAX. The total diameter of the cable is labeled as 12 MIN TYP.



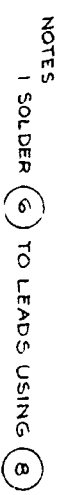
- 1ST WINDING - BIFILAR, 10 TURNS OF ② WOUND CLOCKWISE.
2ND WINDING - BIFILAR, 10 TURNS OF ② WOUND COUNTER CLOCKWISE.
3RD WINDING - BIFILAR, 10 TURNS OF ② WOUND CLOCKWISE.

NOTE.

1. CONSTRUCT PER MIL-T-27.



REV STATUS OF SHIT'S		QTY	QTY	PART OR IDENTIFYING NO	DESCRIPTION	REF DES OR REMARKS	ITEM NO
SHT	1	2					
REV	D	C					
		-2	-1		LIST OF MATERIAL		
UNDER STUDY/DESIGN ENG-ENG DIVISIONS AND ALL SOURCE INFORMATION CHECKED BY: <i>W</i> DATE: <i>1/5/73</i> APPROVED BY: <i>W</i> DATE: <i>1/5/73</i> ENG: <i>W</i> DATE: <i>1/6/73</i>				BOSE CORPORATION FRAMINGHAM, MASS 01701 TITLE TRANSFORMER FLY - EACK			
MATERIAL CONDUCTIVE * 02-33-8-0219				CODE IDENT NO 32108 SIZE C DRAWING NO 100534 REV D			
FINISH OR TREATMENT				SCALE FULL UNIT WT SHEET 1 OF 2			
USED ON				Doc Cont 25			



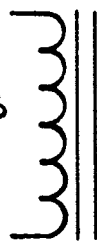
QTY		QTY		PART OR IDENTIFYING NO		DESCRIPTION		REF DES OR REVISIONS		ITEM NO	
REQD		- 2 -		- 1 -		LIST OF MATERIAL					
UNITED AIRWAYS AIRCRAFT CORPORATION ONE 10 BUCKINGHAM BOULEVARD NEW YORK 17, NEW YORK 10018				AIRCRAFT 7-1000 10018		MATERIALS 10018		MATERIALS 10018		MATERIALS 10018	
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MATERIALS 10018				MATERIALS 10018							

NOTE:

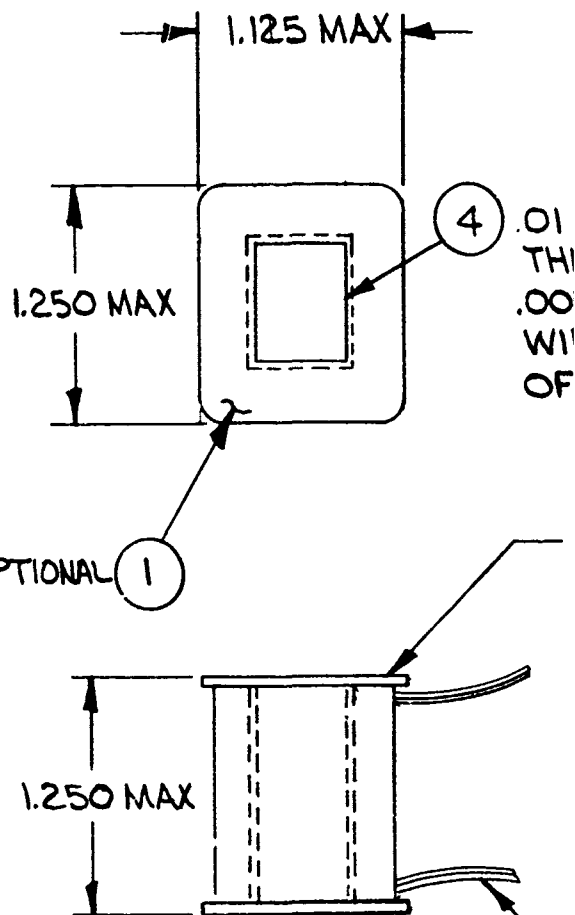
TRANSFORMER IS BUILT IN ACCORDANCE
WITH MIL-T-27C TYPE DESIGNATION (TF 5 VX 36 ZZ ---).

200 ± 1 TURNS
#24 AWG

SCHEMATIC



BOBBIN OPTIONAL



TESTS

L = 100 MH MIN
R = 1.5 OHM MAX
1000V HYPOT WINDING TO CORE

		UNLESS ARE IN
		SURFA ROUGH
		MATE
		FINIS
100832	4126	
NEXT ASSY.	USED ON	

REVISIONS			
REV.	DESCRIPTION	DATE	APPR.
B	REDRAWN	11-3-72	R.W.

.01 MINIMUM INSULATION THICKNESS ON INSIDE OF WINDING;
.005 MINIMUM INSULATION BETWEEN WINDING LAYERS AND ON OUTSIDE OF WINDING.

FLANGE OPTIONAL

2 3 10" LEADS TYP

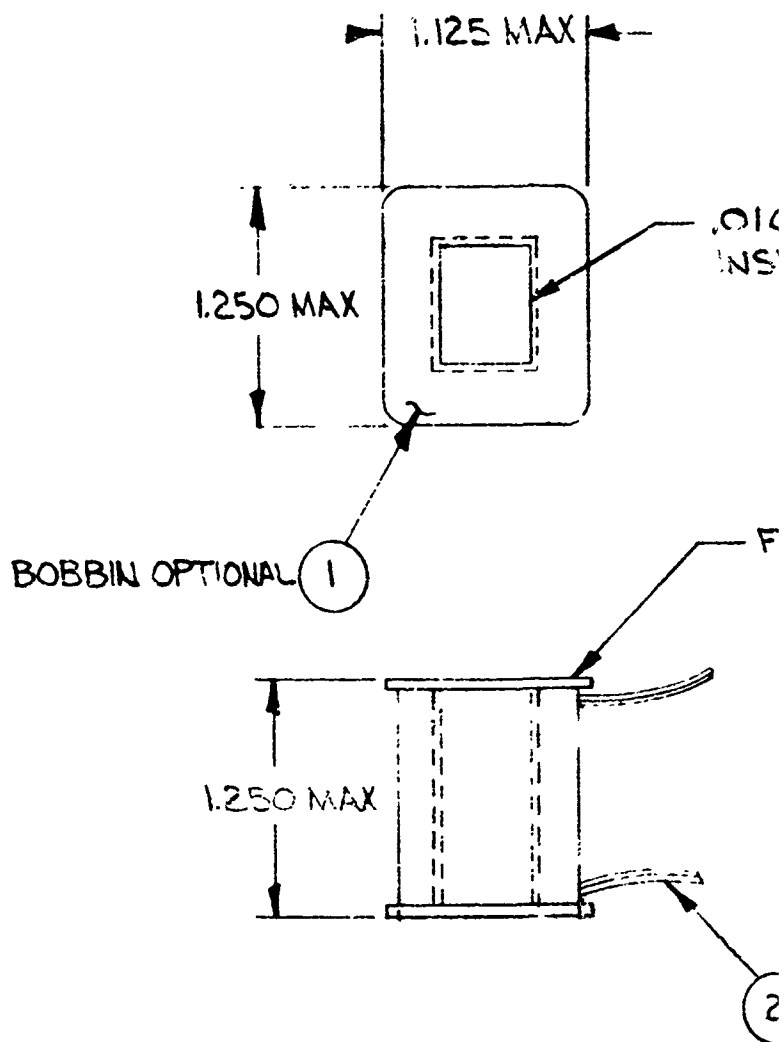
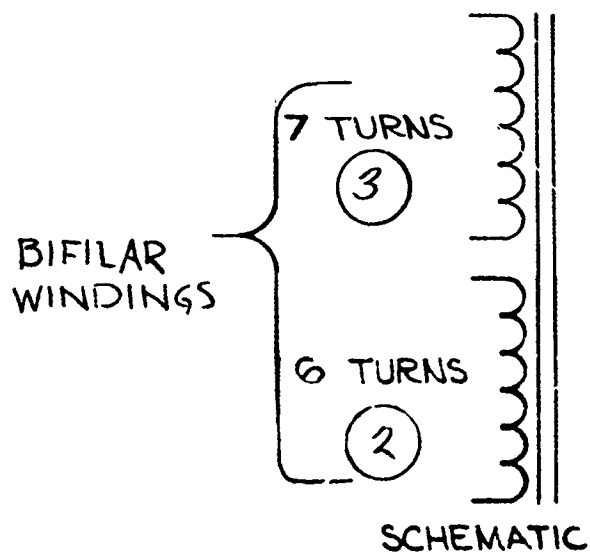
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON		DRAF. <i>D. Zeek</i>	DATE 11-3-72	BOSE CORPORATION FRAMINGHAM, MASS. 01701	
SURFACE ROUGHNESS	ANGLES ± 30'	DECIMALS .X ± .030 FRACTIONS .XX ± .010 ± 1/64	CHECKER <i>RW</i>	TITLE TRANSFORMER, CURRENT SENSING, SECONDARY WINDING	
MATERIAL	ENG. <i>QAR</i>		11/15/73	11/16/73	
FINISH	CONTRACT # DAAB 07-72-C-0219			CODE IDENT. NO. 32108	SIZE B
				DRAWING NO. 100837	REV. B
			SCALE 1:1	UNIT WT	SHEET 1 OF 1

				REVISIONS															
				LTR	DESCRIPTION											DATE	APVD		

REV STATUS OF SHEETS	REV SHEET	-	-																
		1	2																

DRAFTSMAN <i>D. Zeek</i>	DATE <i>11-3-72</i>	CONTRACT NO. <i>DAAB</i>	BOSE CORPORATION NATICK, MASS. 01760		
CHECKER <i>RW</i>	<i>1/15/73</i>	<i>07-72-C-0219</i>			
ENG <i>GAZ</i>	<i>1/16/73</i>	TITLE TRANSFORMER DRIVE SECONDARY WINDING			
APPROVAL		CODE IDENT. NO. 32108	SIZE <i>A</i>	DRAWING NO. <i>PL 100839</i>	LTR <i>-</i>
APPROVAL		SCALE	UNIT WT.	SHEET <i>1 OF 2</i>	

NOTE :
 TRANSFORMER IS BUILT IN ACCORDANCE
 WITH MIL-T-27C TYPE DESIGNATION (TF5VX32ZZ...)



TESTS

L = 100.4H MIN (EACH WINDING)
 1000V HYPOT { WINDING TO CORE
 WINDING TO WINDING

		UNLESS OTHERWISE SPECIFIED
		SURFACE ROUGHNESS
		MATERIAL
		FINISH
100832	4126	
NEXT ASSY	USED ON	

REVISIONS			
REV.	DESCRIPTION	DATE	APPR.
B	REDRAWN	11-3-72	RW

.010 MINIMUM INSULATION
INSIDE & OUTSIDE OF WINDING

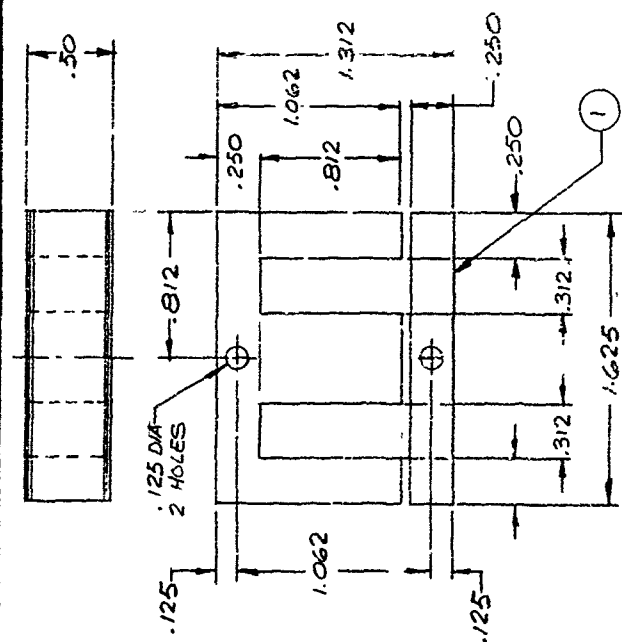
FLANGE OPTIONAL

(2) (3) 6" LEADS TYP

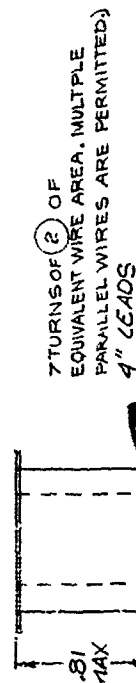
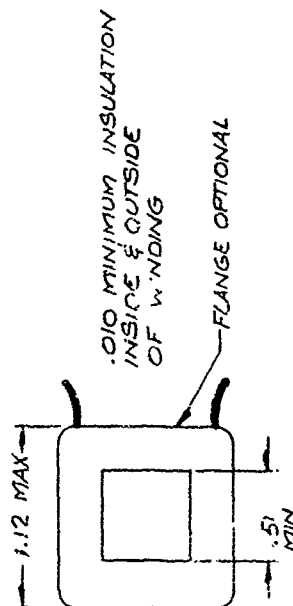
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON		DRAF. <i>D. Zeek</i>	DATE 11-3-72	BOSE CORPORATION FRAMINGHAM, MASS. 01701	
SURFACE ROUGHNESS	ANGLES ± 30'	CHECKER <i>RW</i>	DATE 1/15/79	TITLE TRANSFORMER, DRIVE SECONDARY WINDING	
	DECIMALS ± .030	ENG. <i>JAR</i>	DATE 1/16/79	CODE IDENT. NO. 32108	SIZE B
MATERIAL	FRACTIONS ± 1/32			DRAWING NO. 100839	REV. B
FINISH	± .005	CONTRACT # DAAB		SCALE 1:1	UNIT WT.
		07-72-2-0219		SHEET 1 OF 1	25

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVAL
A	CHG. WIRE SIZE & NO. OF TURNS	11/10/73	PLW 1/13/73
B	ADDED NOTE 1	11/13/73	PLW 2/1/73

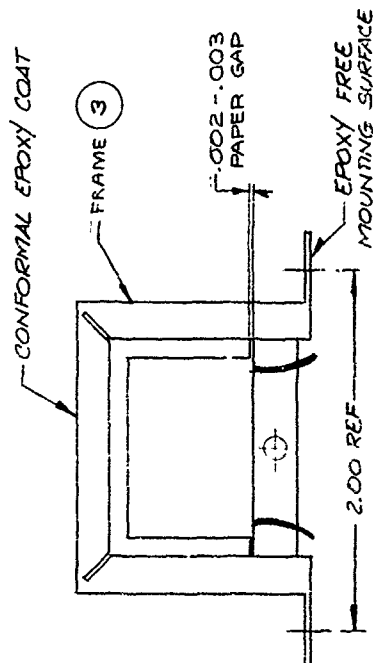
NOTE.
1. CONSTRUCT PER MIL-T-27.



CORE (SQUARE STACK)
29 GAGE LAMINATIONS
51-1/2 PATTERN
MATERIAL: SILICON STEEL (AISI TYPE M-15)

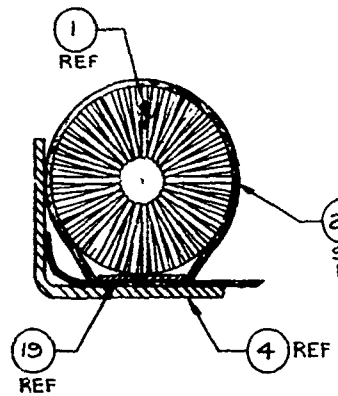
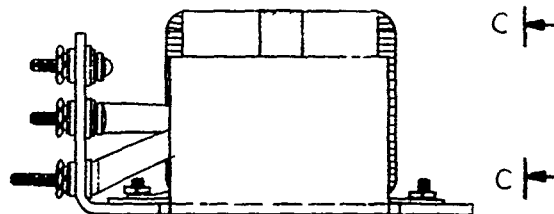
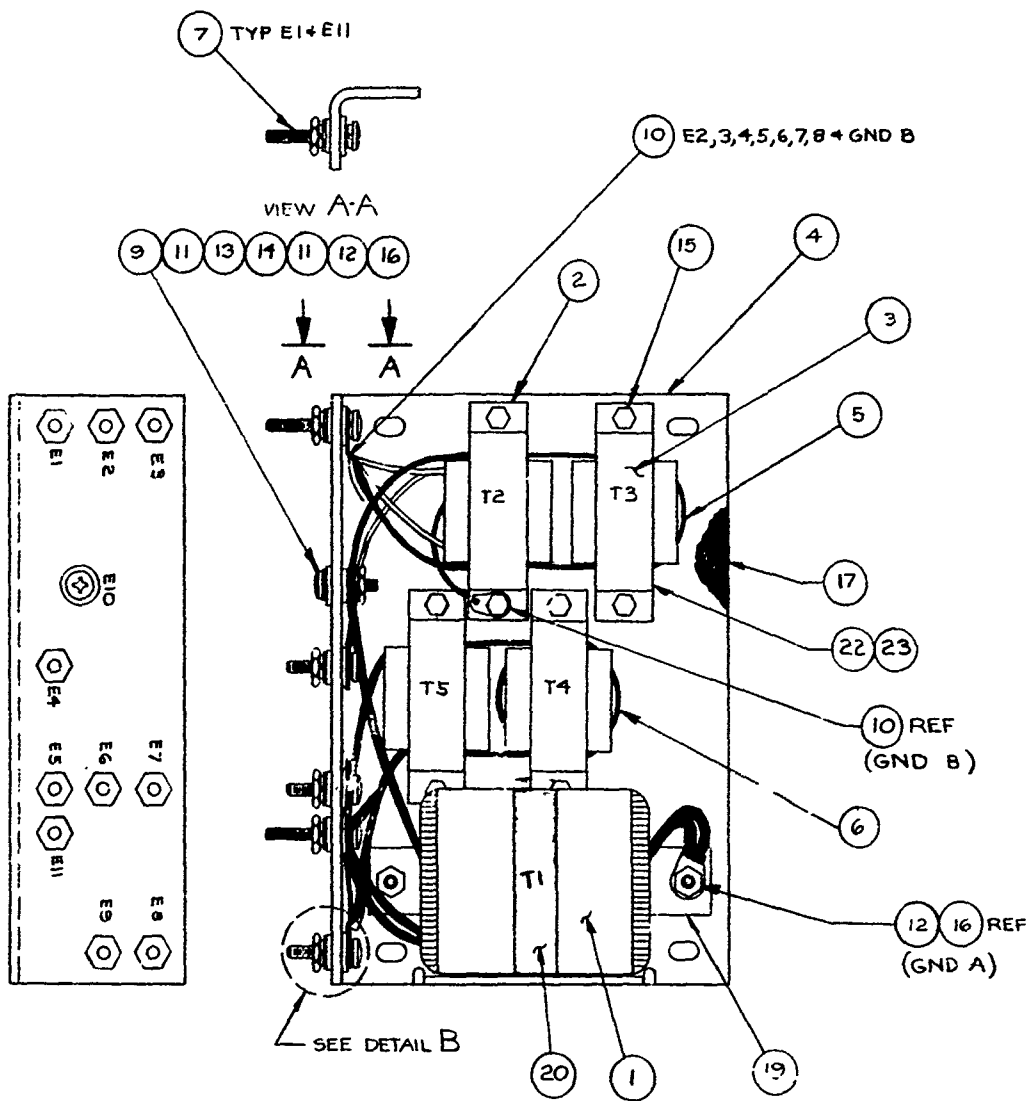


OPTIONAL BOBBINS:
ANTERLINE #8155
OR THERMOTECH #4-107

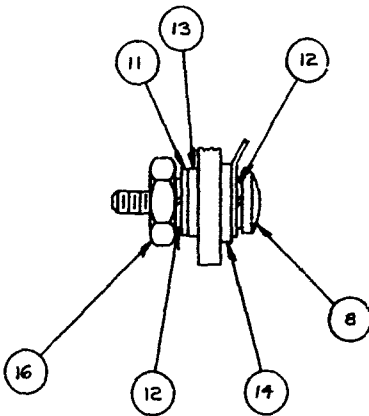


TESTS R = .002 OHM MAX
1000 V HYPOT WINDING TO CORE

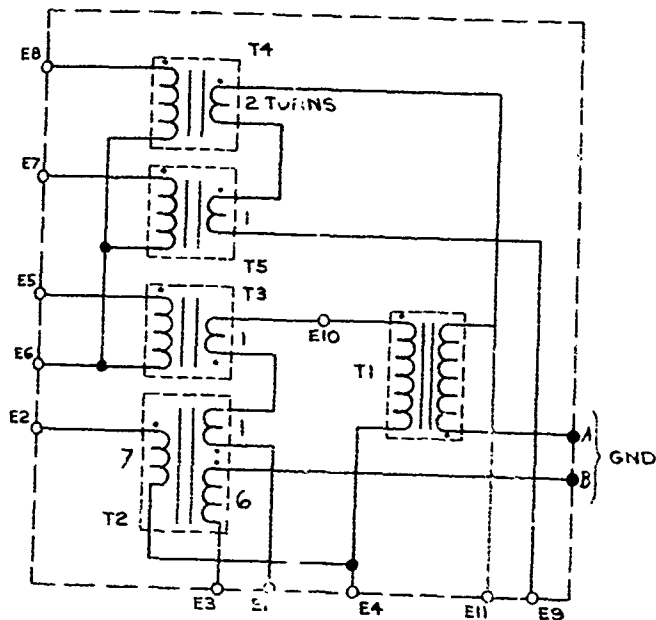
QTY. REQD	PART OR IDENTIFYING NO.	DESCRIPTION	REF. DES. OR REMARKS	ITEM NO.
-2	-1	INDUCTOR		
LIST OF MATERIAL				
MATERIAL		DATE	BOSE CORPORATION FALMOUTH, MASS. 01970	
MATERIAL		DATE	TITLE INDUCTOR EMI FILTER	
MATERIAL		DATE	CODE CONT NO	
MATERIAL		DATE	SIZE	
MATERIAL		DATE	CHASSIS NO.	
MATERIAL		DATE	REV.	
MATERIAL		DATE	B	
MATERIAL		DATE	100843	
MATERIAL		DATE	32108 C	
MATERIAL		DATE	SCALE 2:1	
MATERIAL		DATE	UNIT WT.	
MATERIAL		DATE	SHEET	



VIEW C-C



DETAIL B
SCALE 2:1



SCHEMATIC

NOTES

1 SOLDER ALL CONNECTIONS USING (E1)

(20) REF
SHOWN ENLARGED
FOR CLARIFICATION

(2) REF

QTY. REQD.	QTY. REQD.	ZONE	PART OR IDENTIFYING NO	DESCRIPTION	REF DES OR REMARKS	ITEM NO
-2	-1					
LIST OF MATERIAL						
DRAFTSMAN NAPOLITANO A DATE 11/6/72 CHECKER RW 1/16/73 DNE JAE 1/16/73 CONTRACT NO. DAAB07-72-C-0219 APPROVAL APPROVAL			BOSE CORPORATION NATICK, MASS 01760 TITLE POWER MAGNETICS SUB-ASSEMBLY CODE IDENT NO 32108 SIZE D DRAWING NO. 100832 LTR -			
MATERIAL FINISH OR TREATMENT NEXT ASST 4126 USED ON			SCALE FULL UNIT WT SHEET 1 OF 1 Doc. Cont.			

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421 CDR, US Army Missile Command Redstone Scientific Info Ctr ATTN: Chief, Document Section 002 Redstone Arsenal, AL 35809	

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